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HUMAN FACTORS STUDIES. CONFORMAL/PLANAR ARRAY.(U)

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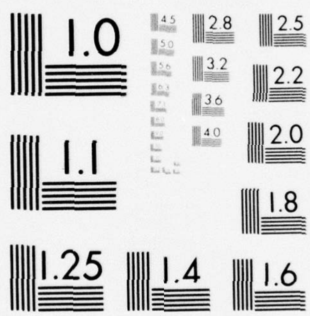

MICROCOPY RESOLUTION TEST CHART
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Document Number
TRACOR 66-562-C
Contract N123(953)54996A
Serial No. 2110-227
Task Number 8

TECHNICAL MEMORANDUM

HUMAN FACTORS STUDIES (U)
Conformal/Planar Array

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Submitted To
Conformal/Planar Array
Project Office
Code 2110 - USNEL

30 September 1966

GROUP 4
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Task Number 8

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ABSTRACT

The Conformal/Planar Array was studied from the Human Factors viewpoint. The study produced: human factor source documents, a description of a detailed Human Factors Program Plan, system-operator information flow charts, and man-machine tradeoff considerations. Specifically, the report contains the following items:

a. A partially Annotated Bibliography of titles organized into seven major areas of interest to design groups. In addition, an index of representative human factors parameters keyed to the Annotated Bibliography was included as a convenience.

b. A detailed Human Factors Plan organized to show the logically sequenced tasks required for a human factors effort to support the Conformal/Planar Array System Design. The plan indicates the relationships among project management, system design, and the detailed Human Factors Tasks. The plan also delineates, within each task, the relevant inputs, processes, and outputs including feedback loops to other Human Factor tasks. A task and time schedule is included along with manning requirements.

c. A set of information flow charts. The charts depict the kind of input-output information required for system operation at various functional levels including the kinds of information categories required of operators.

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d. A man-machine tradeoff study. Tables are included showing the rating factors applied to the tradeoffs considered and how competitive factors were evaluated.

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1. INTRODUCTION

This report contains the results of work on Task Assignment Number 8, Conformal/Planar Array: Human Factors Studies, performed by TRACOR, Inc., Austin, Texas, under U. S. Navy Contract N123(953)54996A, U. S. Navy Electronics Laboratory, San Diego, California, dated July 26, 1966. The Human Factors Studies comprise one task in a series of tasks required for studying general C/P Array requirements during the Concept Formulation Stage. The task reported on herein addressed itself to the following problems:

- Obtaining preliminary data on human factors source documents.
- Developing a detailed Human Factors Plan for participating in the design effort aimed at assuring operability, supportability, and trainability of the system.
- Preparing functional information flows within the projected personnel subsystem and between it and other subsystems.
- Conducting initial human factor trade-off studies considering such factors as level of automation, back-up capability, and multi-purpose displays.

The report is divided into the following three sections: Introduction, Technical Effort, and Conclusions and Recommendations. An Annotated Bibliography and an Index to General Human Factors Parameters are presented as Appendixes.

The Technical Effort of the report contains a description of the Annotated Bibliography of over 200 source

documents of human factors parameters relevant to the C/P Array. Also, there is an organized index of these parameters cross-indexed to the bibliography for easy reference in future work. A Detailed Human Factors Plan was prepared which describes the sequence of Human Factor Tasks and the requirements for their performance, the relationships among the Human Factors Tasks and the requirements for their performance, the relationships of the Human Factors Tasks to System Design and Project Planning Personnel, and finally, a Task and Time Schedule along with Manning Requirements, Memorandum and Reports information. The Human Factors Technical Effort also resulted in several levels of analysis of the functional flow of information necessary for system performance. Man-machine functional information flows were identified in terms of categories of input-output information required by the sonar operating personnel for performing assigned functions in their relationship to more general functional system information flows.

The final portion of the Technical Effort presents the results of trade-off studies for Automatic vs. Manual Classification Clue Evaluations, Multi-Mode vs. Single Operator Functional Displays, and Automatic System vs. Manual System Control.

The Annotated Bibliography and Index of General Human Factors Parameters are presented in Appendices.

2. TECHNICAL EFFORT

The first portion of the Technical Effort contains a description of the Annotated Bibliography and Index of General Human Factors Parameters. This is followed by a discussion of the Detailed Human Factors Program Plan describing the tasks to be performed, the relationships among these tasks, the relationship of the Human Factors Program to System Design and the Project Planning Personnel, Task and Time Schedules, and Manning Requirements. The third portion of the Technical Effort contains Information Flow Charts starting at the System level and continuing down to the operator level where categories of input-output information are identified. A detailed description of the information flows is also presented. The fourth section contains a discussion and analysis of the trade-offs considered, the methodology and criteria used, and a summary of the trade-off results.

2.1 DESCRIPTION OF THE HUMAN FACTORS ANNOTATED BIBLIOGRAPHY AND PARAMETER INDEX

The Human Factors Annotated Bibliography (see Appendix A) was prepared from source documents furnished from TRACOR files and the Naval Electronics Laboratory.

The bibliography provides the reader with a partially annotated report which has studied critical human factor parameters in connection with the design of the display systems.

An attempt was made to provide sufficient information in the annotations for the reader to decide whether the article provided useful human factors parametric data.

The documents reviewed have been divided into seven major sections.

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I. Display Systems
II. Console Design
III. Information Presentation
IV. Operator Performance
V. Maintenance
VI. Personnel and Training
VII. General References

In the above sections, further breakdowns into subsections, such as information processing, display symbology, vigilance, etc., are made. Within the subsections, the bibliographic entries are listed alphabetically. The entries are numbered consecutively throughout the bibliography.

An index of general human factors parameters was also prepared (see Appendix B). The purpose of this index is to allow the reader to determine whether a particular parameter of interest has been referenced in the Annotated Bibliography of Appendix A. The numbers following the index entry refer to the numbered entries in the bibliography which contain information about the Human Factors parameter of interest.

2.2 DETAILED HUMAN FACTORS PLAN, CONFORMAL/PLANAR ARRAY

The objective of the Detailed Human Factors Plan, Conformal/Planar Array, is to present a comprehensive human factors program for establishing operability, maintainability, and personnel planning information procedures for the Concept Formulation Phase of the Conformal/Planar Array project. The plan can be used to provide appropriate guidance to system hardware and software elements in order to assure a high degree of operability and maintainability at acceptable cost, and to develop and document personnel planning information and manpower requirements for selection, training and trainer devices.

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The Detailed Human Factors Plan is focused primarily on the man-machine interface for operator personnel stationed at display sonar consoles where sonar information is presented and evaluated and from which outputs are used for command and control. The plan details the inputs, processes, outputs, and feedback loops which must be considered in the examination and study of the man-machine interfaces required to accomplish the several type missions.

The overall concept or approach used in the HF Plan is the systematic and logical development of man's role in a large, complex system. The Human Factors Plan Flow Charts, Figures 2.2-1 and 2.2-2, present an overview of the sequencing of tasks that must be accomplished to assure that the criteria of operability, maintainability, and trainability for the system have been met. Detailed examination of each task in the HF Plan is made in paragraphs 2.2.1 through 2.2.14.

In order to indicate the level of the main interfaces and integration with the C/P Array Plan and at the same time avoid the constant repetition of the functional systems in the C/P Array, the following list of such systems are understood to be involved in the Human Factors analysis:

- o Systems
  - ·ASW System
  - ·Communications System
  - ·AAW System
  - ·SW System
  - ·EW System
  - ·Ship System
  - ·Integrated Combat System
  - ·C/P Array Sonar System
  - ·Unit Command System

FIGURE 2.2-1 HUMAN FACTORS PLAN FLOW CHART, FY 1967

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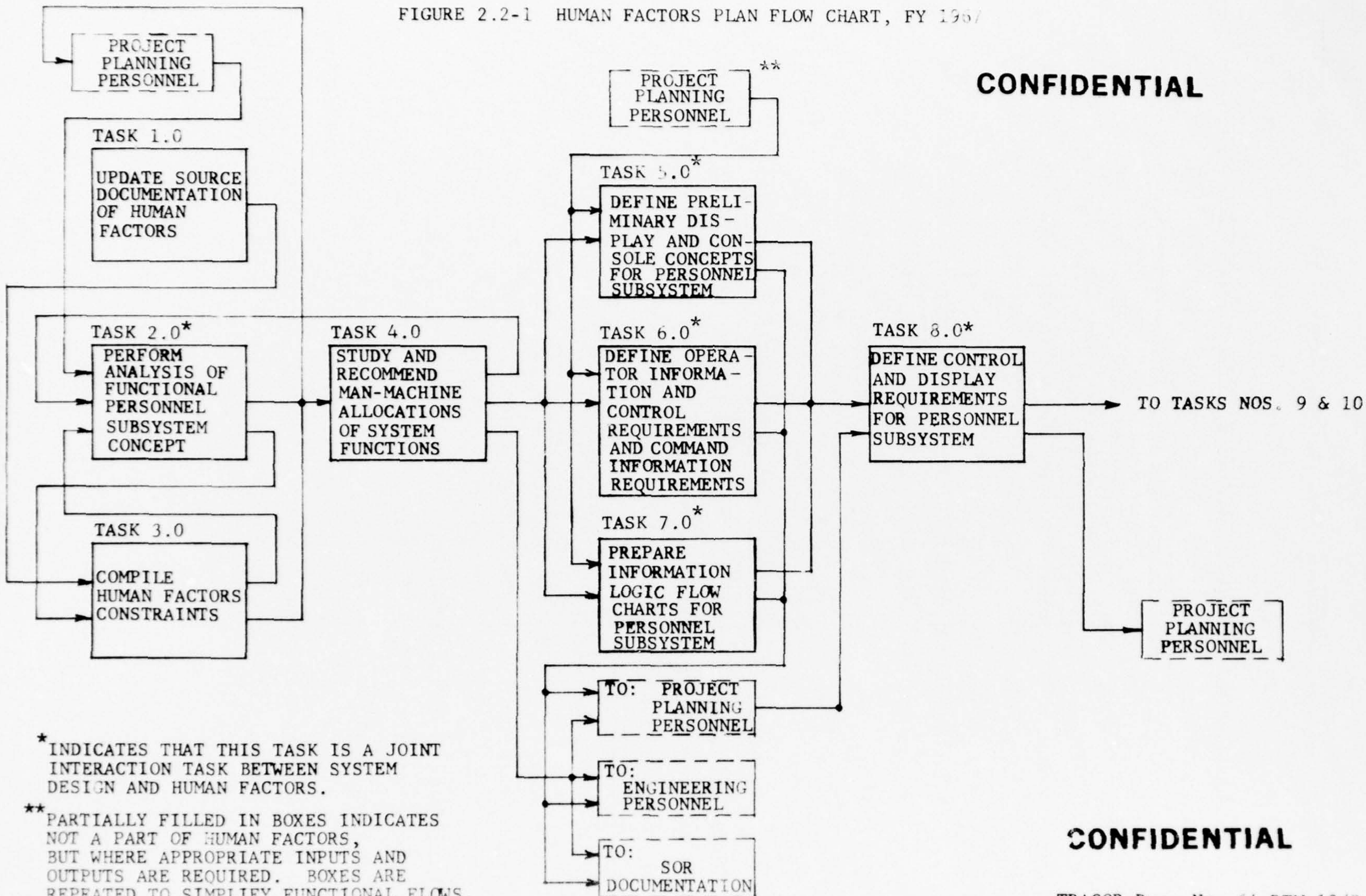

*INDICATES THAT THIS TASK IS A JOINT INTERACTION TASK BETWEEN SYSTEM DESIGN AND HUMAN FACTORS.

**PARTIALLY FILLED IN BOXES INDICATES NOT A PART OF HUMAN FACTORS, BUT WHERE APPROPRIATE INPUTS AND OUTPUTS ARE REQUIRED. BOXES ARE REPEATED TO SIMPLIFY FUNCTIONAL FLOWS.

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FIGURE 2.2-2 HUMAN FACTORS PLAN FLOW CHART, FY 1968

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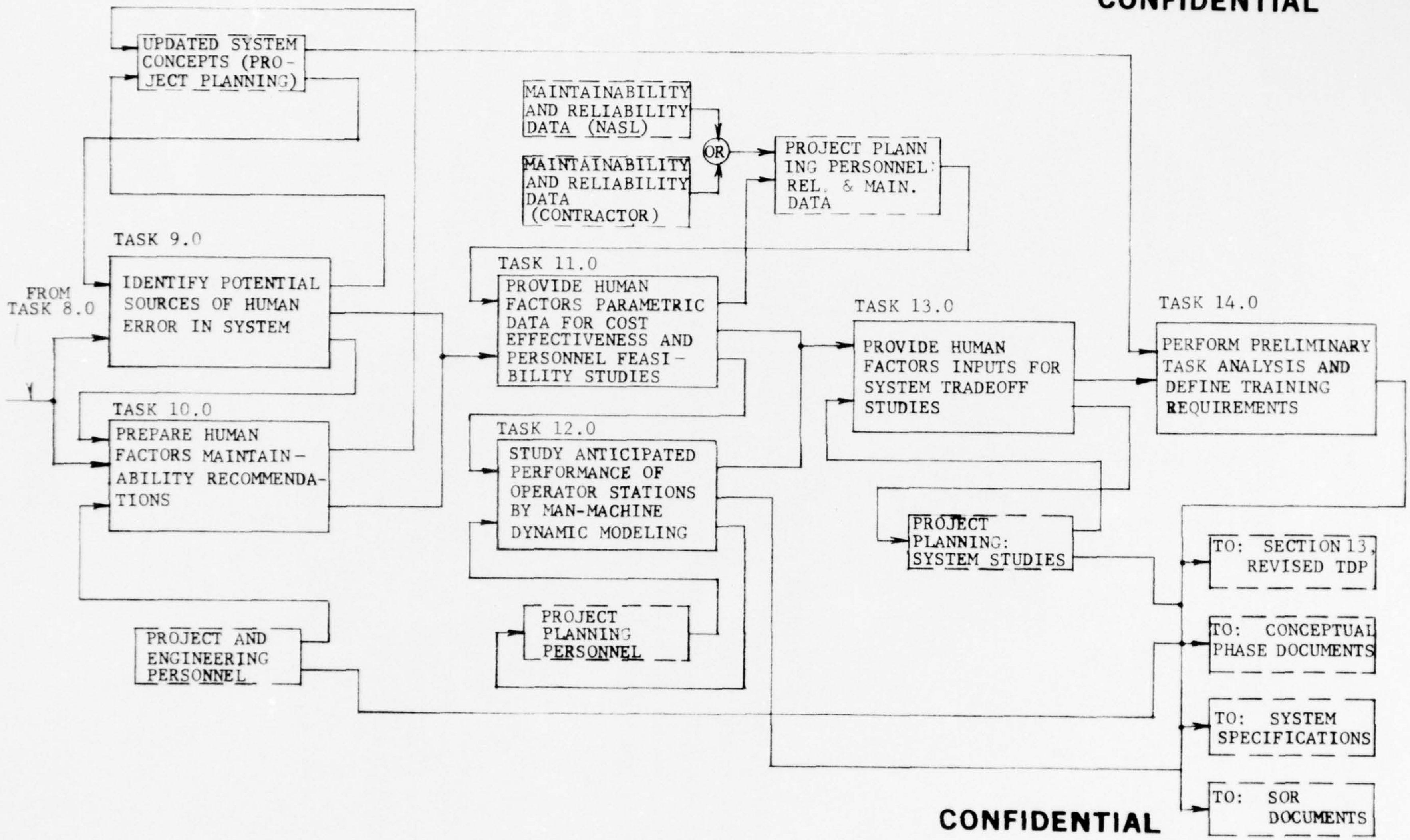

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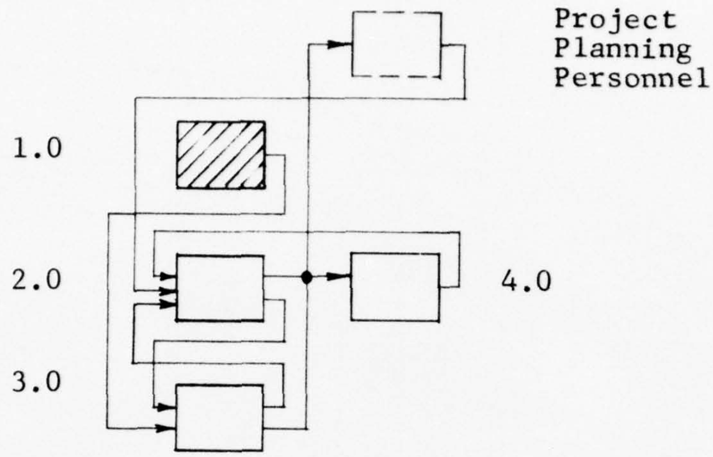
2.2.1 Source Document Updating of Human Factors (Task 1.0)

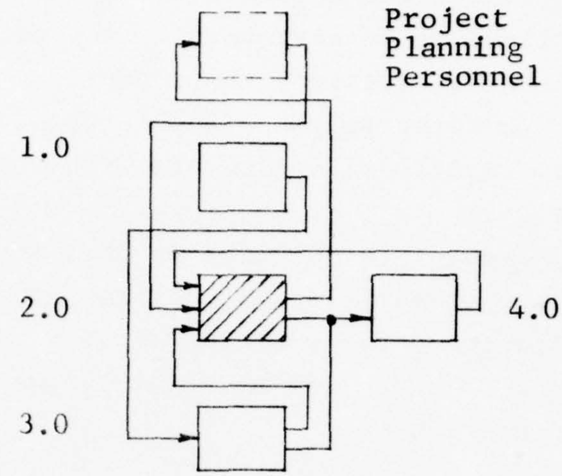


The inputs required for this task will be the initial bibliography included in this report, newly available studies presenting descriptions of the functional systems for the C/P Array System, studies which present man's reliability in his role as an operator in large-scale systems, experimental data from governmental and non-governmental laboratories which are relevant to capabilities and limitations of operators, and training data in terms of time and costs for increasing operator reliability for large-scale systems.

The process required is the behavioral classification of all documents so that ready access is available to studies presenting critical human factors parameters pertaining to operators in the C/P Array System.

The output required is the alphabetically and behaviorally classified documents. It is an essential input to Task 3.0.

2.2.2 Personnel Subsystem Functional Analysis (Task 2.0)



The inputs required for this task are the list of selected missions for the 1970 time frame, a breakdown of each mission into operational phases along with predicted times to perform each phase during a mission, the probable type tactical target(s) to be encountered, the probable personnel organization needed to operate the system and perform mission tasks, and the modular functional equipments required for use by personnel for each functional subsystem.

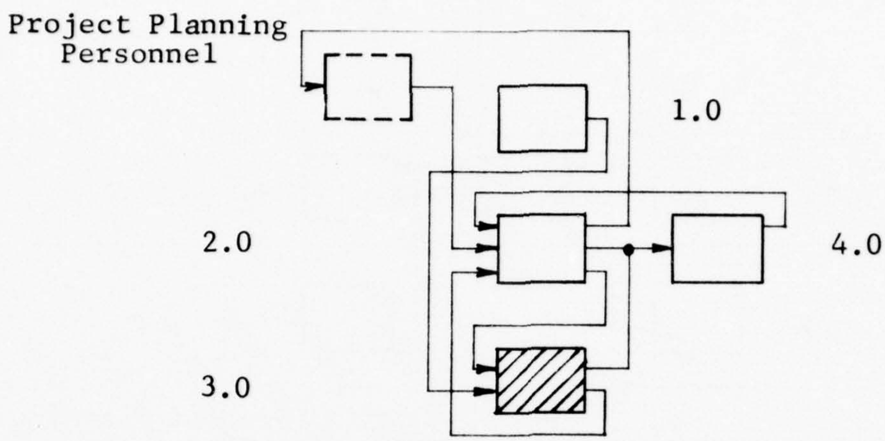
The process required is to organize the inputs listed above, using a type mission, into a time-dimensionalized matrix. The COLUMNS of the matrix will provide the breakdown of phases and sub-phases of a given mission and their predicted time constraints; the ROWS of the matrix will be formed by the functional subsystems and modules with which the personnel must interface; and the CELLS of the matrices will contain extended time-bars identified appropriately in the matrix so as to be useful for future analysis. The purpose of this analytical process is to organize on a systematic basis, at all appropriate functional levels, all anticipated functions

initially assigned to operators during a typical mission.

The outputs required are the identification of the necessary functions to be performed by the personnel subsystem to accomplish a given mission, their durations, and their proper coding according to phase and subphase of a mission as well as the relevant functional equipments with which the operators will interface.

The feedback is positive in that the outputs will be used to make systematic determinations of all subsequent operator functions and tasks at the detailed level; however, the outputs from Task 2.0 are immediately essential to Tasks 4.0, 5.0, 6.0, and 7.0.

2.2.3 <u>Human Factors Constraints (Task 3.0)</u>



The <u>inputs</u> required for this task are the outputs generated during Task 1.0 and the gross functional tasks required of operators generated by the outputs produced during Task 2.0.

The <u>process</u> required is the systematic analysis of all predicted functional tasks required during typical missions for operations, maintainability, and manning of the system for mission performance in relation to known human factor constraint parameters. Special consideration will be given to the fact that an operator's function may not be critical during one portion of a mission but the same operator function may be very critical during another portion.

The <u>output</u> required is a compilation of human factor constraint parameters in relation to system performance during a typical mission. The compilation must be organized for use by Project Planners, Engineers, and for SOR documentation as well as for Task 4.0, performed by Human Factors Personnel.

The <u>feedback</u> loop is negative to Task 2.0 and positive to Task 4.0.

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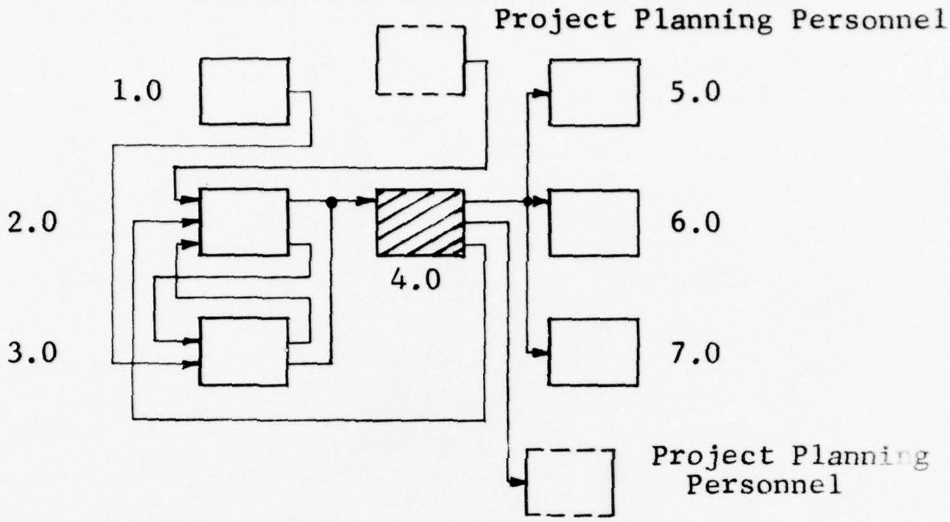
2.2.4 Man-Machine Subsystem Functions Allocations (Task 4.0)



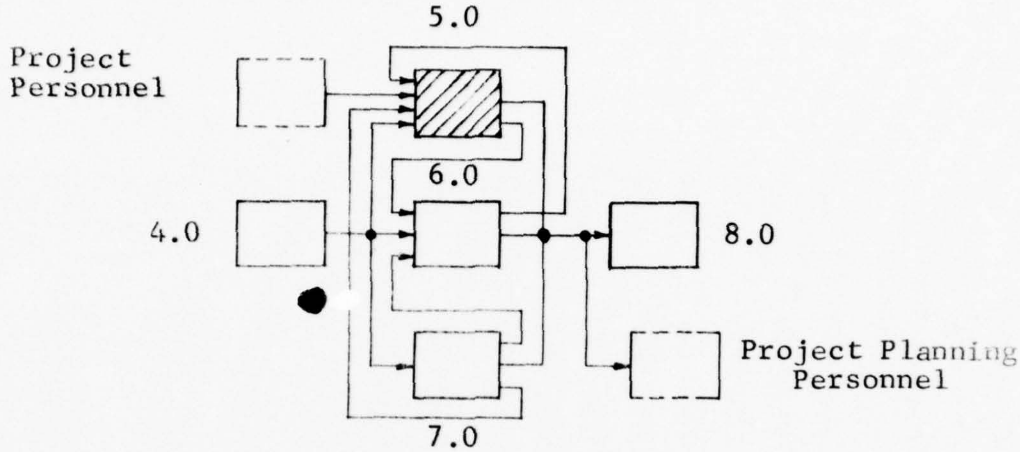
The inputs required for this task are the outputs from Tasks 2.0 and 3.0. The primary input is from the compilation of critical human factors determined from the analysis of Task 3.0.

The process involved is the systematic organization and identification of personnel subsystem functions classified according to whether the functions are best the responsibility of a man or a machine.

The output involved is a preliminary recommendation of all system functions classified as to their assignment to man or machine and the basis for each assignment. Data will be sent to Project Planning, Engineering Personnel, and to SOR documentation.

Two feedback loops are required: the first is positive to Tasks 5.0, 6.0, and 7.0; the second is negative to Task 2.0, where appropriate changes will be re-considered in system operation.

2.2.5 Definition of Preliminary Display and Console Concepts For Personnel Subsystem (Task 5.0)



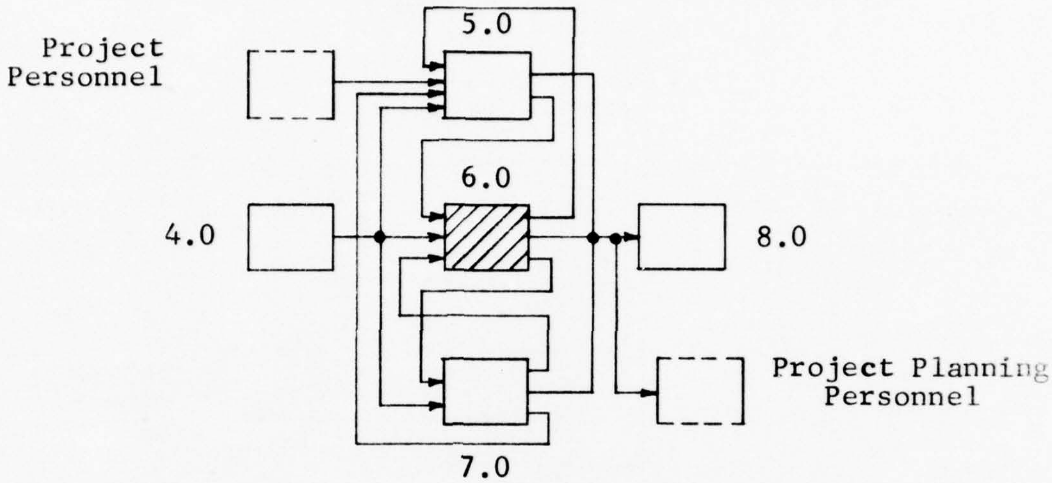
The inputs required for this task are primarily from the preliminary recommendations of system functions allocations arrived at from the output in Task 4.0. Other inputs must be tentatively available from parallel on-going Tasks 6.0 and 7.0 so that an iterative process is generated from the inputs and outputs from all three tasks. Updated information will be furnished by Project Personnel.

The process involved is the systematic definition of the display and console concepts in terms of required information flow for system operation and mission performance. Specific static or dynamic anthropometric considerations for human operators will not be required; however, appropriate assumptions should be made explicit. A preliminary link analysis will be performed.

The output produced is a set of display and console concepts logically related to information flow for system operation and mission performance where human operators are involved.

The feedback loops are negative and iterative within Tasks 5.0, 6.0, and 7.0. Outputs are received by Project Personnel.

2.2.6 Definition of Operator Information/Control and of Command Information Requirements, (Task 6.0)



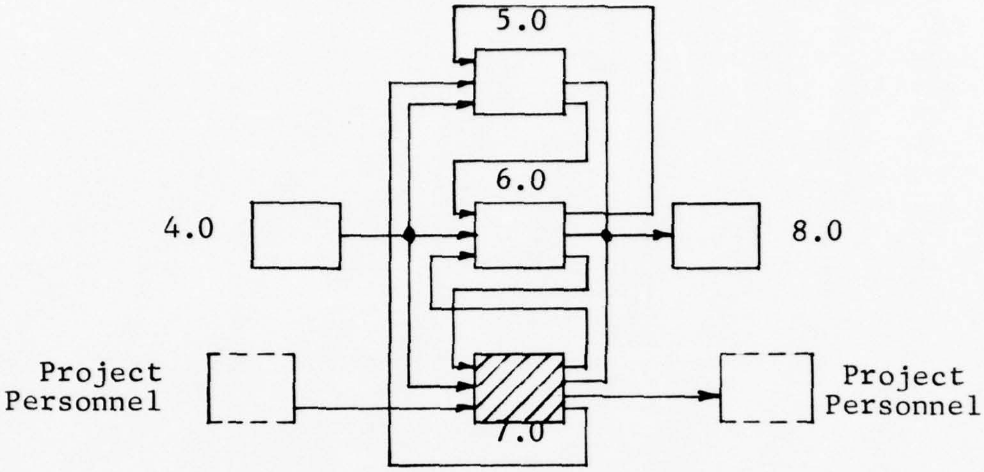
The inputs required for this task are primarily from the preliminary recommendations of system functions allocations received from the output in Task 4.0. Other inputs must be tentatively available from parallel on-going Tasks 5.0 and 7.0 so that an iterative process is generated from the inputs and outputs from all these three tasks. Updated information will be provided by Project Personnel.

The process involved is the systematic definition of operator and control requirements for information based upon man-machine flow charts, and the systematic definition of command information requirements also based upon mutually consistent man-machine flow charts.

The output required is the definition of operator information and control requirements as well as command information requirements. The scope of the information for operator and command must include safety and life support information as well as mission tasks and ship operations.

The feedback loops are both positive and negative as for Task 5.0.

2.2.7 Information Logic Flow Chart Preparation for Personnel Subsystem, (Task 7.0)



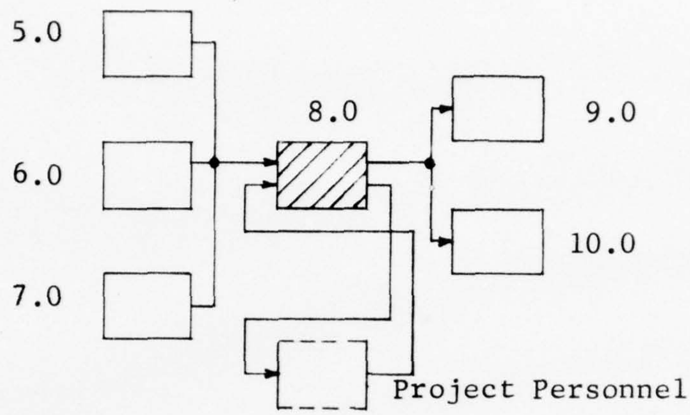
The inputs required for this task are primarily from the preliminary recommendations of system functions allocations arrived at from the output in Task 4.0. Other inputs, however, must be concurrently available from parallel activities on-going in Tasks 5.0 and 6.0 even though only tentative. The project office will furnish alternative designs.

The process involved is the preparation of logic flow charts defined by MIL-H-24148(SHIPS), for each system design representing the information flows to operators from machines and to machines from operators as well as to and from personnel in the command network.

The outputs required are the several logic flow charts representing information flows for each system design for operators and command. Information flow must include safety, life support, and psychological decisions, as well as mission tasks and ship operations. The flow charts will be made available to project personnel.

The feedback loops are to Tasks 5.0, 6.0, and 8.0.

2.2.8 Definition of Control and Display Requirements for Personnel Subsystem, (Task 8.0)



The inputs required for Task 8.0 are all the outputs generated from Tasks 5.0, 6.0, and 7.0. Primary emphasis will be on the outputs from Task 6.0, the operator information and control and command information based upon man-machine and man-flow charting techniques. Updated information will be furnished by Project Personnel.

The process involved is the categorical definition of each control and display in terms of mission tasks, system operation, life support, safety of equipment and personnel, fault detection and isolation, formats, dynamic range, storage characteristics, operational modes, back-up modes, listing of all controls and displays with their approximate location and function.

The outputs are the systematic presentation of control and display functional requirements. Problem areas likely to arise should be discussed in terms of data from Task 3.0 (Human Factors Constraints) and conceptual studies should be proposed where the area is likely to be system critical and type mission

limiting and/or where trade-offs cannot be made without some experimental data.

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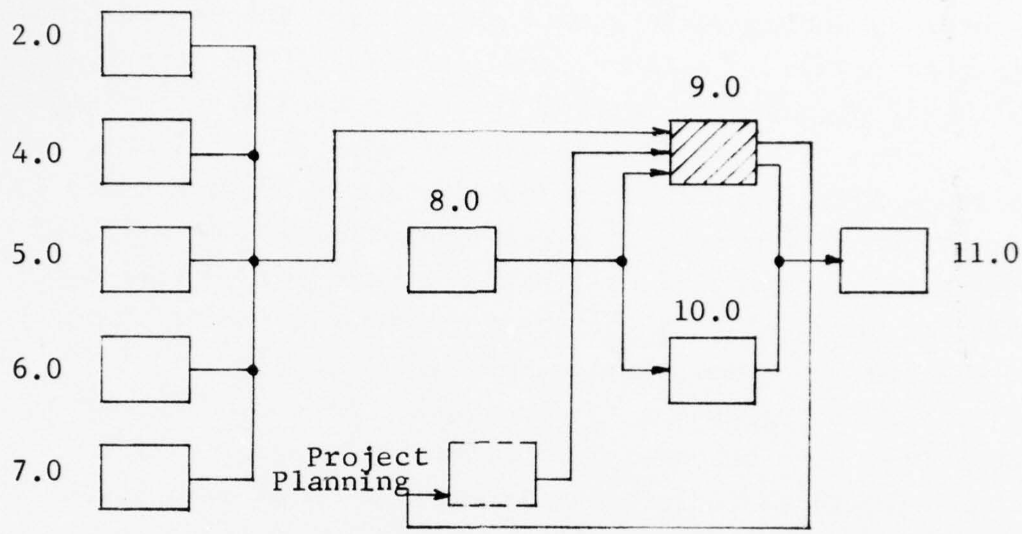
2.2.9 Potential Sources of Human Error in System (Task 9.0)



The inputs required for this task are the data from Tasks 2.0, 3.0, 4.0, 6.0, 7.0 and 8.0. The primary inputs are from Tasks 4.0 and 8.0. Maintainability and reliability data from Project Planning and Engineering Personnel are required on equipment tentatively proposed for alternative systems for: ASW, Communication, AAW, SW, EW, and the Ship's System. Experimental data from control theory parametric studies will be used where available. Updated information will be furnished by Project Personnel.

The process involved should be a form of control theory schematics in which the human transfer function can be derived and relevant human factors parameters identified for operations and for likely potential sources of system degradation due to human operator error, equipment failure due to human error, or both.

The output will be: control theory type of schematics for relevant subsystems in which the sonar operator and supervisor are involved; systematic identification of the human transfer function expected; parametric values for the human

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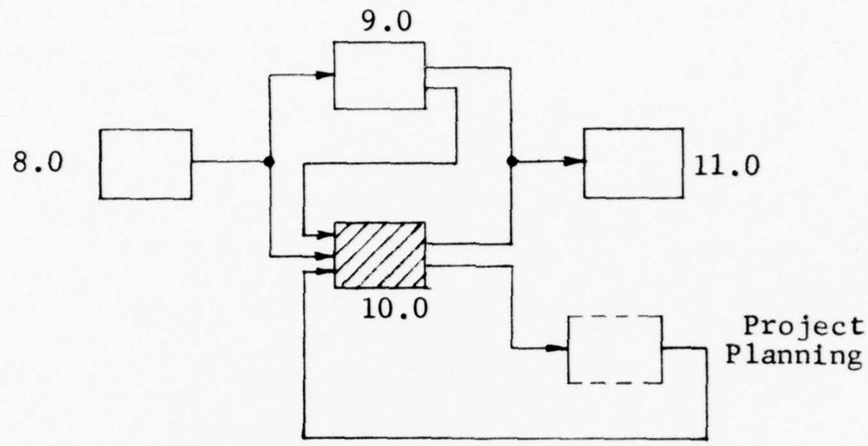
transfer function parameters correlated with experimental data on these parameters; prediction of the capability of the sonar operator to perform maintenance tasks where the degradation is due to equipment failure; prediction of those potential sources of degradation leading to the probability of mission abort, human jeopardy of life, and/or subsystem failure, and the probability that a human operator could prevent these catastrophic failures by the use of appropriate maintenance actions. The potential utilization of the system will be predicted based on both equipment redundancy and/or the use of the operator in a maintenance role (fault detection, fault isolation, and equipment replacement). Alternative control schematics, with accompanying parametric values, will be prepared so as to reflect the incorporation of maintainability principles, to predict system maintainability for each alternative design, and to define the role of the operator in decreasing system downtime.

The feedback is to Tasks 2.0, 4.0, 5.0, 6.0, 7.0, 8.0. Project Personnel will receive outputs from this task.

2.2.10 Human Factors Maintainability Recommendations (Task 10.0)



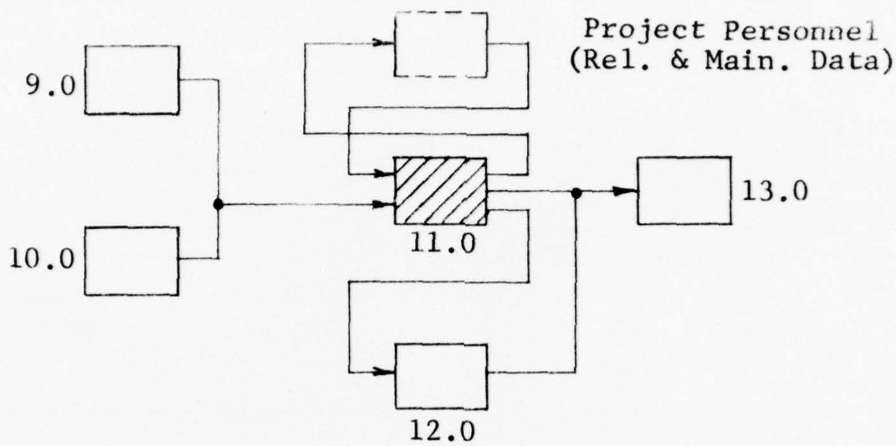
The inputs required for Task 10.0 are those from Tasks 8.0 and 9.0. Updated information is furnished by Project Personnel.

The process involved is the systematic organization of maintainability recommendations in terms of mission performance, life support, and safety predictions for different alternate system configurations and the maintenance role of man in each configuration in terms of a classificatory schematic.

The output is a systematically organized set of maintainability recommendations in terms of mission performance, life support, and safety predictions for different alternative system configurations. A preliminary taxonomy of personnel maintenance tasks will be formulated, based on control theory or similar models.

Project Personnel will receive the outputs from Task 10.0, as well as Personnel Subsystem Planning (Human Factors Personnel).

2.2.11 Human Factors Data For Cost-Effectivess And Personnel Feasibility Studies (Task 11.0)



The inputs required for Task 11.0 are those from Tasks 9.0 and 10.0 and the maintainability and reliability data from NASL or the contractor through Project Personnel.

The process involved is the systematic analysis of the schematics and maintenance recommendations developed in Tasks 9.0 and 10.0 in order to predict the influence of human error on system reliability. Available reliability and maintenance data will be utilized for the alternative design points. Evaluation of the human error factors will be made in terms of marginal analysis.

The output will be human factor data for a schedule of costs for a given amount of system effectiveness (probabilities of success in mission performance), based on selection and training parameters. Assumptions will be explicit concerning the selection and trainability of operators and supervisors.

The feedback is positive to Tasks 13.0 and 14.0. Project Personnel receive data from Task 11.0.

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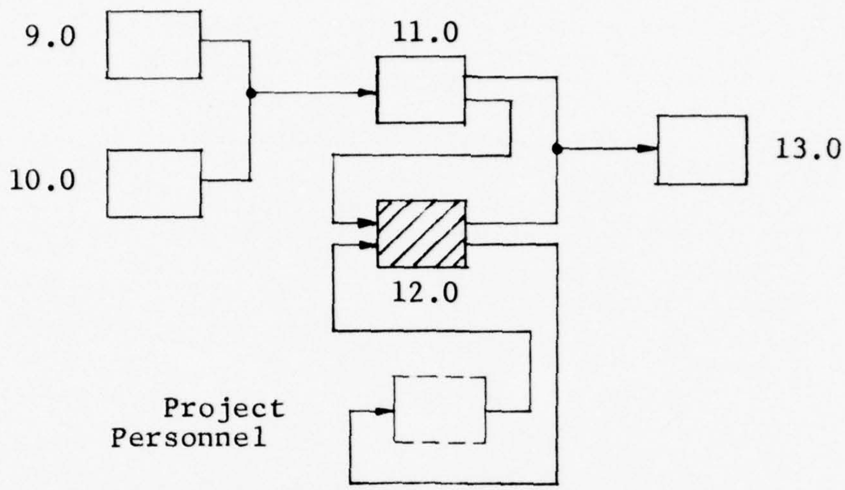
2.2.12 Study of Anticipated Performance of Operator Stations (Task 12.0)



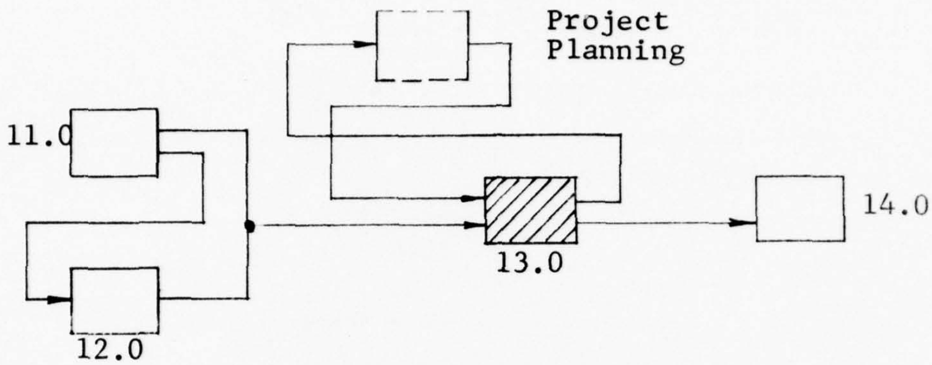
The input required for Task 12.0 are the outputs from Tasks 9.0, 10.0, and 11.0. Updated information is furnished by Project Personnel.

The processes involved are mock-ups of the operator station(s) and a computerized analytic (stochastic-deterministic) model of operator and equipment performances during a typical mission for the selected design approach. Appropriate ranges of input values will be used for supervisory functions and for each proposed operator station in order to exercise detection, tracking, acoustic intercept, target classification, and fire-control functions. The multi-mode display console will be included in the modeling.

The output required is the mock-up of the operator station(s), the analytic model, and the computerized runs.

The feedback is positive to Task 13.0 and to Project Planning and Engineering Personnel.

2.2.13 Human Factors Data For System Trade-off Studies, (Task 13.0)



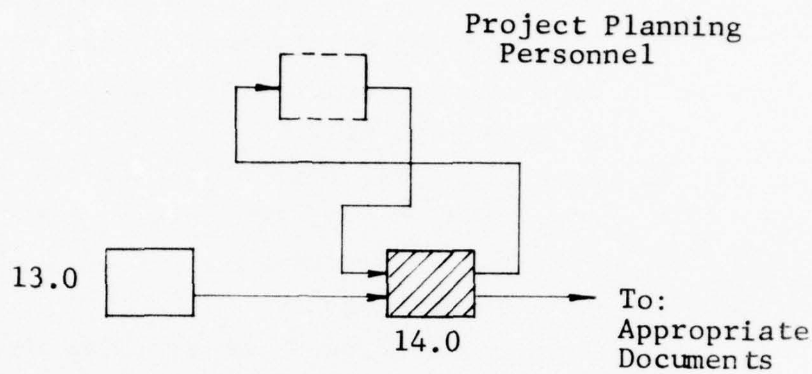
The inputs required for Task 13.0 are the data from Tasks 11.0 and 12.0. Project Personnel will provide alternative design points.

The process involved is the classification of critical human factor parameters in terms of mission and system performance within the constraints of human and equipment safety for alternative design solutions.

The outputs required are the classified human factor parameters for each design alternative.

Outputs are sent to Project Planning and Engineering Personnel.

2.2.14 Preliminary Task Analysis And Training Requirements, (Task 14.0)



The inputs for Task 14.0 are primarily from Task 13.0.

The processes required are: (1) a logical, time-flow of sequential tasks required in the man-man, man-machine subsystem modular interfaces. Events must be represented in a symbology appropriate to inputs, decision, and actions of man and equipment for performing type missions. The tasks will be derived systematically from the data of Task 2.0; (2) a systematic analysis of workloads per unit of time per modular subsystem per operator; (3) the psychological and behavioral classification or taxonomy, if feasible, of operator and maintenance skills per task; (4) and the type and degree of training requirements to perform each task; and (5) the organization of duty positions with the back-up and duty rotations required. The data will be organized for computerization, if feasible.

The outputs will be:

a. Symbolically and temporally organized sequence of tasks for type missions.

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b. System critical task intervals with type tasks involved and number of all tasks in the interval.

c. Psychological and behavioral classification of operator and maintenance skills per task.

d. Type and degree of training requirements to perform each task.

e. Probabilities, that each task can be performed correctly, out of 100 trials, given proper training, under normal, optimal, and worst case conditions.

f. Indication of need for training devices for system critical tasks.

g. Indication of training times for system critical tasks.

h. A description (computerizable) of the personnel organization, duty position, duty rotations, and system critical personnel selection variables, given Navy manpower availabilities.

The <u>feedback</u> is to Project Planning and Engineering Personnel, System Specifications, and Conceptual Phase Documents, as well as SOR Documents.

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2.2.15 Memorandums and Reports

Table 2.2-1 indicates the cognizant agencies and personnel receiving the relevant memorandums and reports generated by the Human Factors Plan.

TABLE 2.2-1 MEMORANDUMS AND REPORTS

No.	TASK	HFD	PRASD	PROJECT PLANNING	ENGINEERING	NASL	CONTRACTOR
1	Source Document Updating	X		X			X
2	System Functional Analysis	X	X	X	X		X
3	Human Factors Constraints	X		X	X		X
4	Man-Machine System Functional Allocation	X		X	X		X
5	Preliminary Display & Console Concepts	X		X	X		X
6	Operator Information/Control & Command Info.Reqmts.			X	X		X
7	Information Logic Flow Charts			X	X		X
8	Control and Display Reqmts.	X		X	X		X
9	Sources of Human Error	X	X	X	X	X	X
10	Maintainability Recommendations	X		X	X	X	X
11	Cost-Effectiveness & Personnel Feasibility Studies	X	X	X	X		X
12	Performance of Operator Stations			X	X		X
13	Trade-Off Studies			X	X		X
14	Task Analysis & Training Reqmts.	X	X	X	X		X

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2.2.16 Tasks and Time Schedules

The Task and Time Schedule for the Detailed Human Factors Plan is shown in Table 2.2-2. This is a comprehensive schedule providing a logical sequence of events for the orderly achievement of technical work leading to acceptable Human Factors design criteria. Assumptions are made that relevant inputs to Human Factors personnel are properly organized and timely so as to facilitate the type of reformulations and analysis required for the accomplishment of the Detailed Human Factors Plan and to provide needed inputs to other engineers and agencies when expected by them.

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TABLE 2.2-2 HUMAN FACTORS PLAN: TASK AND TIME SCHEDULE

		FY 1967			FY 1968				FY 1969		
		2nd QTR	3rd QTR	4th QTR	1st QTR	2nd QTR	3rd QTR	4th QTR	1st QTR	2nd QTR	3rd QTR
No.	HUMAN FACTORS TASKS	O N D	J F M	A M J	J A S	O N D	J F M	A M J	J A S	O N D	J F M
1	Source Document Updating										
2	Personnel Subsystem Functional Analy.										
3	Human Factor Constraint Compilation										
4	Man-Machine System Function Allocation										
5	Preliminary Display and Console Concepts Definition										
6	Operator Information/Control and Command Information Definition										
7	Information Logic Flow Chart Preparation										
8	Control and Display Requirements Definition										
9	Potential Sources of Human Error										
10	Maintainability Recommendations										
11	Cost Effectiveness and Personnel Feasibility Studies										
12	Study of Anticipated Performance of Operator Stations										
13	Trade-off Studies										
14	Preliminary Task Analysis and Training Requirements										
15	Memorandum and Reports										

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2.2.17 Human Factors Plan: Task-Manning Requirements, (Table 2.2-3)

The Task-Manning Requirements for the Human Factors Plan are indicated below by Task Number, Fiscal Year and Quarter, Month, Men per Month and Totals by Month, Quarter, and by Year.

Assumptions are made that the following human factors personnel are available for the HF Program Plan:

a) Ph.D.s with 5-7 Years Human Factors Experience, or
b) M.A.s with 8-10 Years Experience, or
c) B.A.s with 11-15 Years Experience.

Senior personnel must have had actual experience with advanced design studies and to have had experience with design groups to include avionics, reliability, maintainability, operations analysis, mock-up personnel, computer personnel, and system/mission functional analyses. Formal education should preferably be in Psychology (or related sciences), or some combination of science and engineering involving the human element.

TABLE 2.2-3. HUMAN FACTORS PLAN: TASK-MANNING REQUIREMENTS **CONFIDENTIAL**

(CONCEPT FORMULATION STAGE)

		FY 1967									FY 1968												MAN YRS		HF Plan
		2nd QTR		3rd QTR			4th QTR			1st QTR			2nd QTR			3rd QTR			4th QTR				TOTALS		
TASK No.	HUMAN FACTORS PLAN TASKS	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	1967	1968	TOT.
1.0	Source Document Updating	1	1																				2		2
2.0	Functional Personnel Sub-system Analysis	1	1	1																			3		3
3.0	Human Factors Constraint Compilation			1	1																		2		2
4.0	Man-Machine Functional Allocation				1																		1		1
5.0	Preliminary Display & Console Concepts					1	1																2		2
6.0	Operator & Command Information Reqmts.					1	1	1															3		3
7.0	Information Logic Flow Charts							1	1														2		2
8.0	Control and Display Reqmts.								1	2	1												3	1	4
9.0	Sources of Human Error										1	2	2											5	5
10.0	Maintainability Recommendations													1	1	1								3	3
11.0	Cost-Effectiveness & Personnel Studies													1	1	1								3	3
12.0	Performance of Operator Stations																2	2	1					5	5
13.0	Data For Trade-Off Studies																		1					1	1
14.0	Task Analysis and Training Reqmts.																			2	2	2		6	6
	TOTAL: MONTH	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	18	24	42
	TOTAL: QTR			6			6			6			6			6			6			6	18	24	42
	TOTAL: YEAR									18									24						42

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2.3 INFORMATION FLOW CHARTS

This section discusses the flow of information between the Sonar System and other ASW Ship Systems and the flow of information within the Sonar System with the Sonar Operators and Sonar Supervisor as the main focal point.

Information flow will be analyzed at four levels. First, the system concept and the personnel organization of the ASW Ship are discussed and all ASW Ship Systems are identified. Secondly, an over-view of the information flow within the Sonar System is presented. Thirdly, a more detailed information flow is presented which links the system and subsystem information flow to operator function. Lastly, the man-machine information flow is described in detail.

The documents used as references for the information flow charts were TRACOR Document No. 66-494-C, ASW Ship Definition, TRACOR Document No. 66-517-C, ESS Baseline Description, NEL Specification 3180-66-2, Specification for a Multimode Sonar Console, C/P Array Preliminary Technical Development Plan, April, 1966, and NEL Document ASW Ship Integrated Combat System, October 1964.

2.3.1 ASW Ship Information Flow

Figure 2.3.1-1 depicts the main flow of information within the total ASW Ship. Responsibility for Own Ship Command resides with the Commanding Officer. The functions of Command and Control are divided into three major areas, Bridge Guidance and Control, Tactical Command and Control, and Weapons Selection and Control, the latter two major functions taking place physically within the Combat Direction Center. Figure 2.3.1-1 shows the manned positions associated with each of these Command and Control functions within dotted circles.

It was central to the concept of the ICS System and the SEA HAWK ship to have a central Data Reduction and Processing

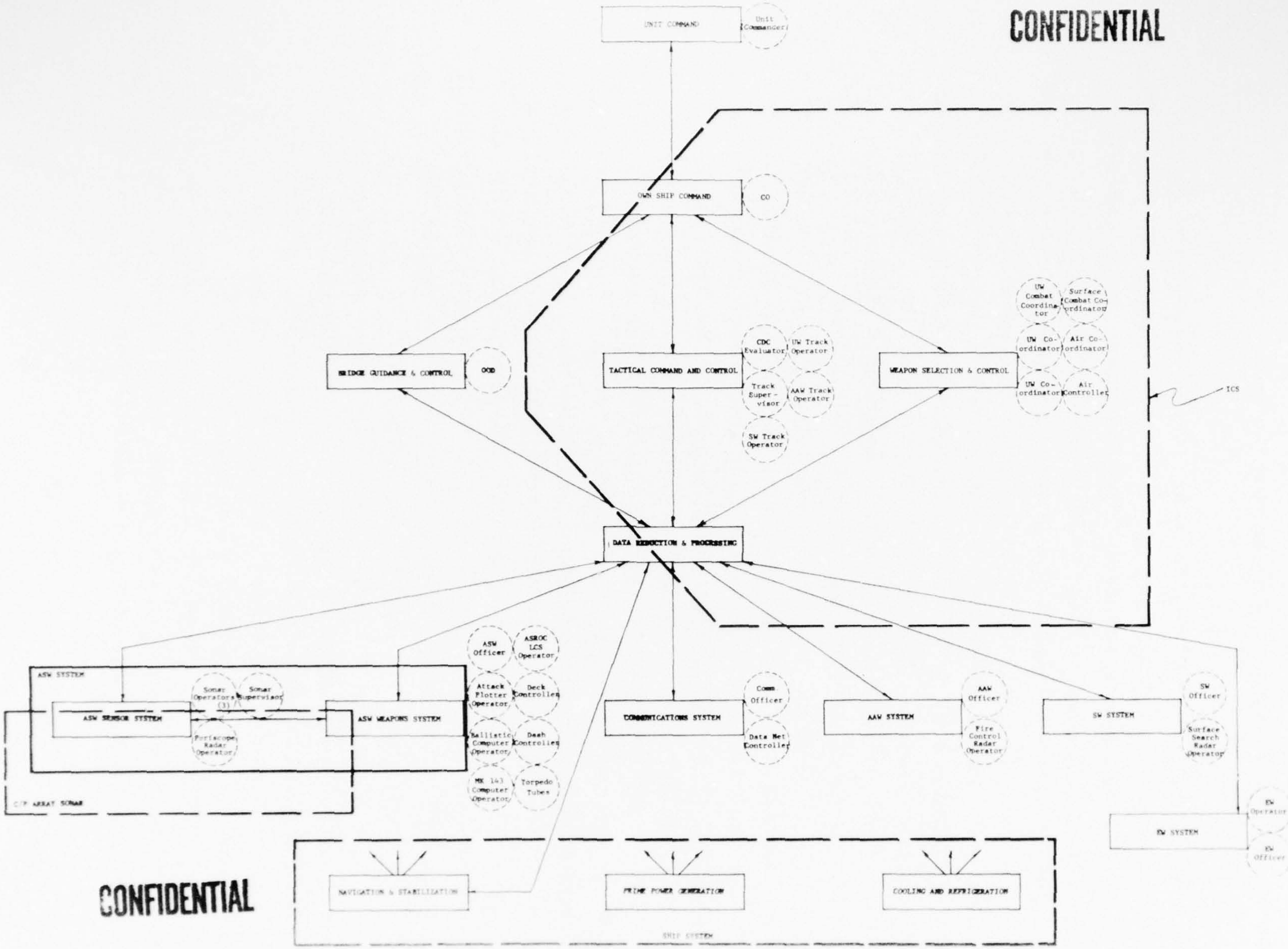

FIGURE 2.3.1-1 ASW SHIP INFORMATION FLOW

TRACOR DWG NO. 20 RTM

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Complex responsible for communications throughout the ship and for man-machine interface at each operator location. Some Data Reduction and Processing facilities, however, are associated separately with each of the major Ship Systems. The majority of communications between the Command and Control functions and the ASW Ship Systems are routed through the Data Reduction and Processing Complex. A dashed line surrounds part of the Own Ship Command, part of the Data Reduction and Processing Complex, all of the Tactical Command and Control functions, and all of the Weapons Selection and Control functions. This area has been designated as the Integrated Combat System.

The major systems on board the ship are the ASW System, the Communications System, the Anti-Air-Warfare System, the Surface Warfare System, and the Electronic Warfare System, all supported by the Ship System which supplies navigation and stabilization signals, prime power, and cooling and refrigeration.

Within the ASW System, there are two subsystems, the ASW Sensor System and the ASW Weapons System. The C/P Array Sonar is the primary ASW Sensor and interfaces very closely with the ASW Weapons System to the extent that certain computations required for fire-control purposes may be provided within the framework of the C/P Array Sonar. This is shown by the dashed lines, indicating the C/P Array Sonar overlapping the ASW Sensor System and the ASW Weapons System.

Thus, the C/P Array Sonar interfaces at the system level with the ASW Weapons System; the Ship System, for prime power, navigation and stabilization, cooling and refrigeration; and those Command and Control functions of the ship which are performed within the Combat Direction Center.

With this organizational description as a point of departure, five operators are assumed within the C/P Array Sonar; three sonar operators, one sonar supervisor, and one

periscope radar operator. The periscope radar is considered to be a portion of the ASW Sensor System, but not a part of the C/P Array Sonar.

2.3.2 Sonar System Information Flow, General

Figure 2.3.2-1 demonstrates the use of the display as the focal point of information flow within the C/P Array Sonar. In accordance with the Preliminary Technical Development Plan, five subsystems are involved in the C/P Array Sonar Program. They are:

a. Active Subsystem
b. Passive Subsystem
c. Torpedo Detection Subsystem and Acoustic Countermeasures
d. Acoustic Intercept Subsystem
e. Acoustic Communication Subsystem

To support the above functional areas, two further subsystems are required. These are:

a. Automatic Fault Isolation and Self-Check (FISC)
b. Automatic Performance Prediction

All of these subsystem functions are under the control of a central data processor contained within the C/P Array Sonar, and not shared with any other System of the ASW Ship. The data processor is used for system and subsystem interface and sonar system control. The data processors interfaces in machine language with other ASW Ship Systems and provides all the digital information required for operator functions to central display units. It is through these displays and via the data processor that the sonar operator communicates with other Ship Systems.

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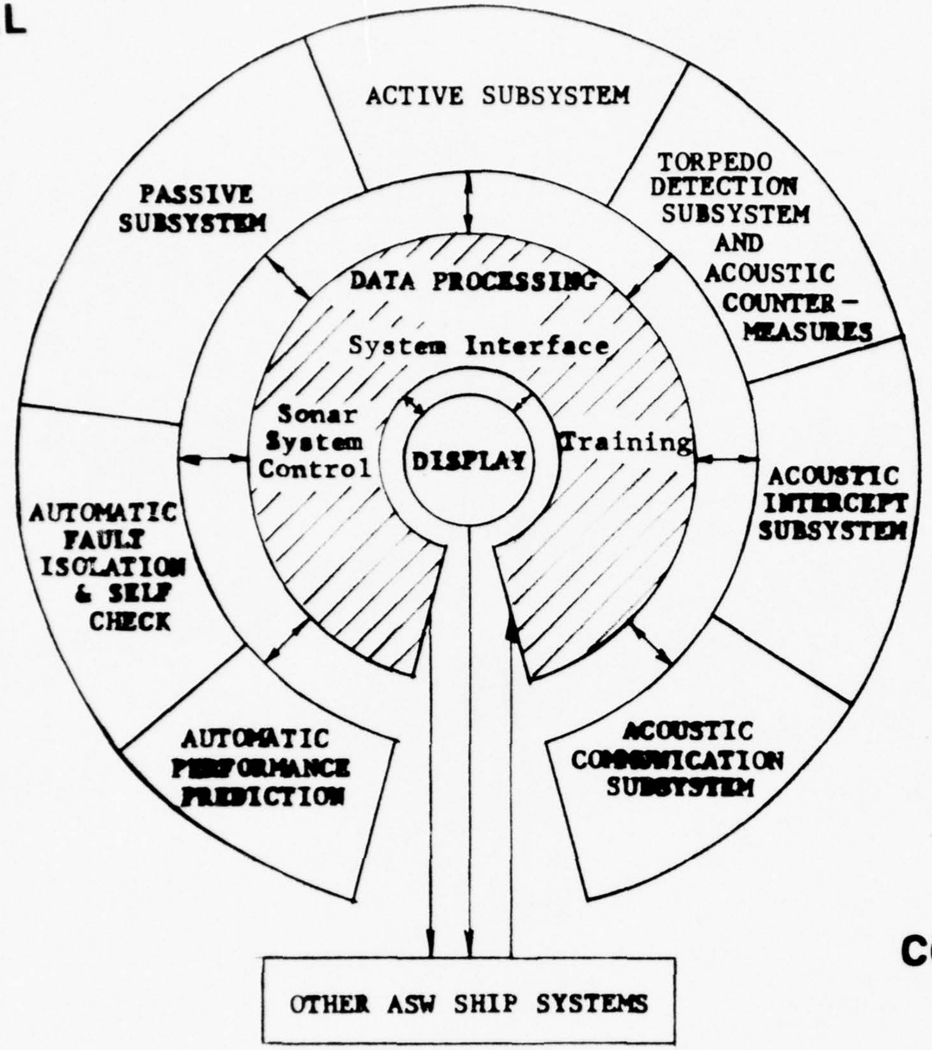

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FIGURE 2.3.2-1 SONAR INFORMATION FLOW-OVERVIEW

TRACOR Drawing No. 50. 9/2/66 R. T. M.

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2.3.3 Sonar System Information Flow

Figures 2.3.3-1 and 2.3.3-2 expand in more detail the information of the previous section. The five major subsystems defined by the Preliminary Technical Development Plan are shown interfacing with the data processor. The Auxiliary Functions of Automatic Fault Isolation and Self-Check and Acoustic Performance Prediction are augmented, for the sake of completeness, by the functions of operator training and system control, almost all of which is performed within the data processor. These latter functions are grouped into the dotted area referred to as Auxiliary Functions (See Figure 2.3.3-1).

The data processor, in turn, is linked to the multimode displays manned by the Sonar Operators, the Sonar Supervisor, and a Radar Display for the Periscope Radar Operator, (See Figure 2.3.3-2). The data processor via the multimode display transmits to the sonar operator information from the ASW Ship System, the Combat Direction Center, and the ASW Weapons System (See Figure 2.3.3-2). These are the areas of major system interface.

The information flow of Figures 2.3.3-1 and 2.3.3-2, are enumerated in detail below.

2.3.3.1 Active Subsystem Information Flow (Figure 2.3.3-1)

a. Inputs

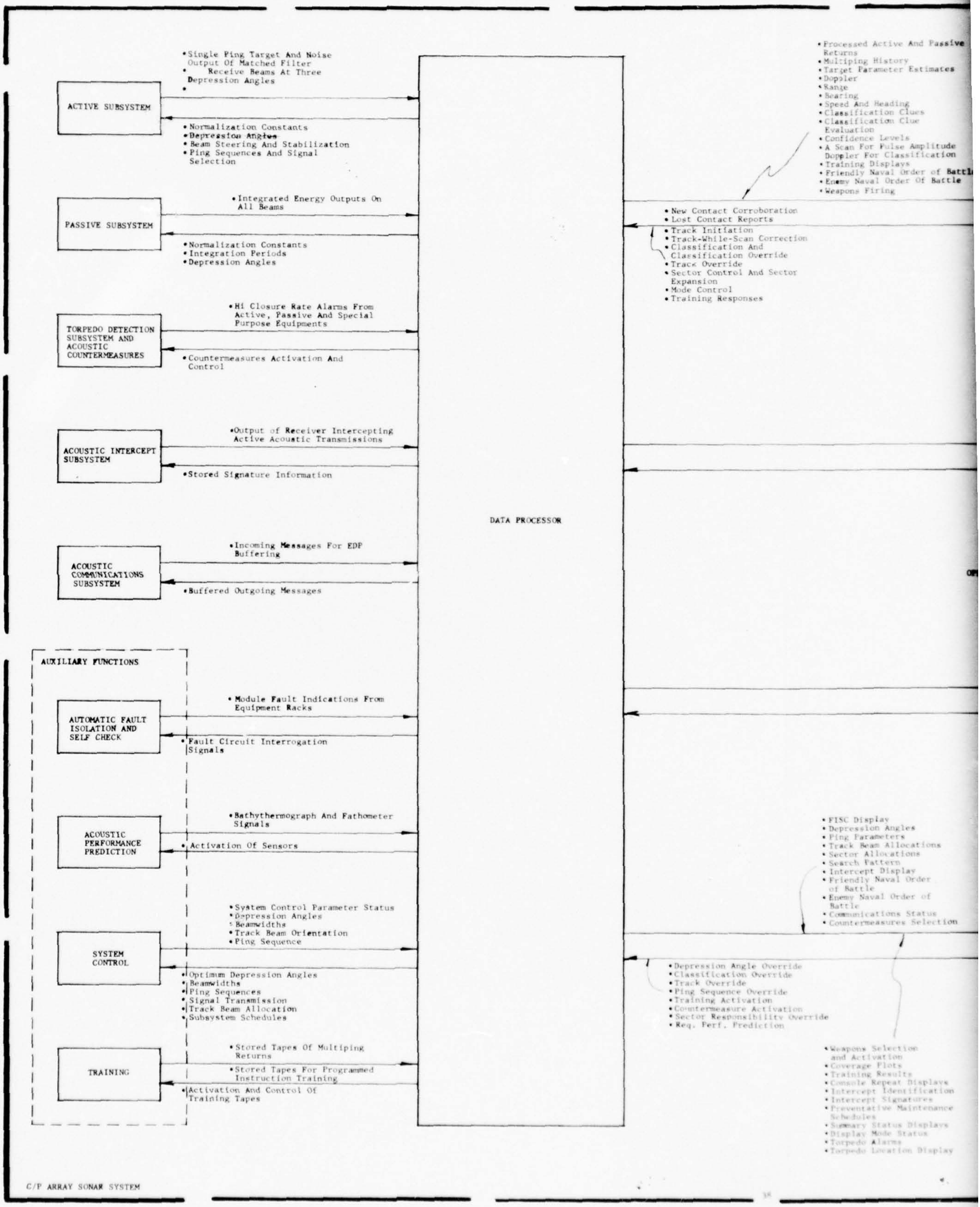
(1) Normalization Constants. For equalization of the noise on all bearings and ranges.

(2) Beam Steering

(3) Ping Sequences

(4) Signal Selection

b. Outputs. Single Ping Target and Noise Output. Information from up to 900 receive beams at 3 depression angles and from up to 15 contacts selected for tracking.



•Single Ping Target And Noise Output Of Matched Filter
• Receive Beams At Three Depression Angles
ACTIVE SUBSYSTEM
• Normalization Constants
•Depression Angles
• Beam Steering And Stabilization
• Ping Sequences And Signal Selection
•Integrated Energy Outputs On All Beams
PASSIVE SUBSYSTEM
•Normalization Constants
•Integration Periods
•Depression Angles
•Hi Closure Rate Alarms From Active, Passive And Special Purpose Equipments
TORPEDO DETECTION SUBSYSTEM AND ACOUSTIC COUNTERMEASURES
•Countermeasures Activation And Control
•Output of Receiver Intercepting Active Acoustic Transmissions
ACOUSTIC INTERCEPT SUBSYSTEM
•Stored Signature Information
•Incoming Messages For EDP Buffering
ACOUSTIC COMMUNICATIONS SUBSYSTEM
•Buffered Outgoing Messages
AUXILIARY FUNCTIONS
•Module Fault Indications From Equipment Racks
AUTOMATIC FAULT ISOLATION AND SELF CHECK
•Fault Circuit Interrogation Signals
•Bathythermograph And Fathometer Signals
ACOUSTIC PERFORMANCE PREDICTION
•Activation Of Sensors
•System Control Parameter Status
•Depression Angles
•Beamwidths
•Track Beam Orientation
•Ping Sequence
SYSTEM CONTROL
•Optimum Depression Angles
•Beamwidths
•Ping Sequences
•Signal Transmission
•Track Beam Allocation
•Subsystem Schedules
•Stored Tapes Of Multiping Returns
•Stored Tapes For Programmed Instruction Training
TRAINING
•Activation And Control Of Training Tapes
DATA PROCESSOR
•Processed Active And Passive Returns
•Multiping History
•Target Parameter Estimates
•Doppler
•Range
•Bearing
•Speed And Heading
•Classification Clues
•Classification Clue Evaluation
•Confidence Levels
•A Scan For Pulse Amplitude Doppler For Classification
•Training Displays
•Friendly Naval Order of Battl
•Enemy Naval Order Of Battle
•Weapons Firing
•New Contact Corroboration
•Lost Contact Reports
•Track Initiation
•Track-While-Scan Correction
•Classification And Classification Override
•Track Override
•Sector Control And Sector Expansion
•Mode Control
•Training Responses
•FISC Display
•Depression Angles
•Ping Parameters
•Track Beam Allocations
•Sector Allocations
•Search Pattern
•Intercept Display
•Friendly Naval Order of Battle
•Enemy Naval Order of Battle
•Communications Status
•Countermeasures Selection
•Depression Angle Override
•Classification Override
•Track Override
•Ping Sequence Override
•Training Activation
•Countermeasure Activation
•Sector Responsibility Override
•Req. Perf. Prediction
•Weapons Selection and Activation
•Coverage Plots
•Training Results
•Console Repeat Displays
•Intercept Identification
•Intercept Signatures
•Preventative Maintenance Schedules
•Summary Status Displays
•Display Mode Status
•Torpedo Alarms
•Torpedo Location Display
OP
C/P ARRAY SONAR SYSTEM

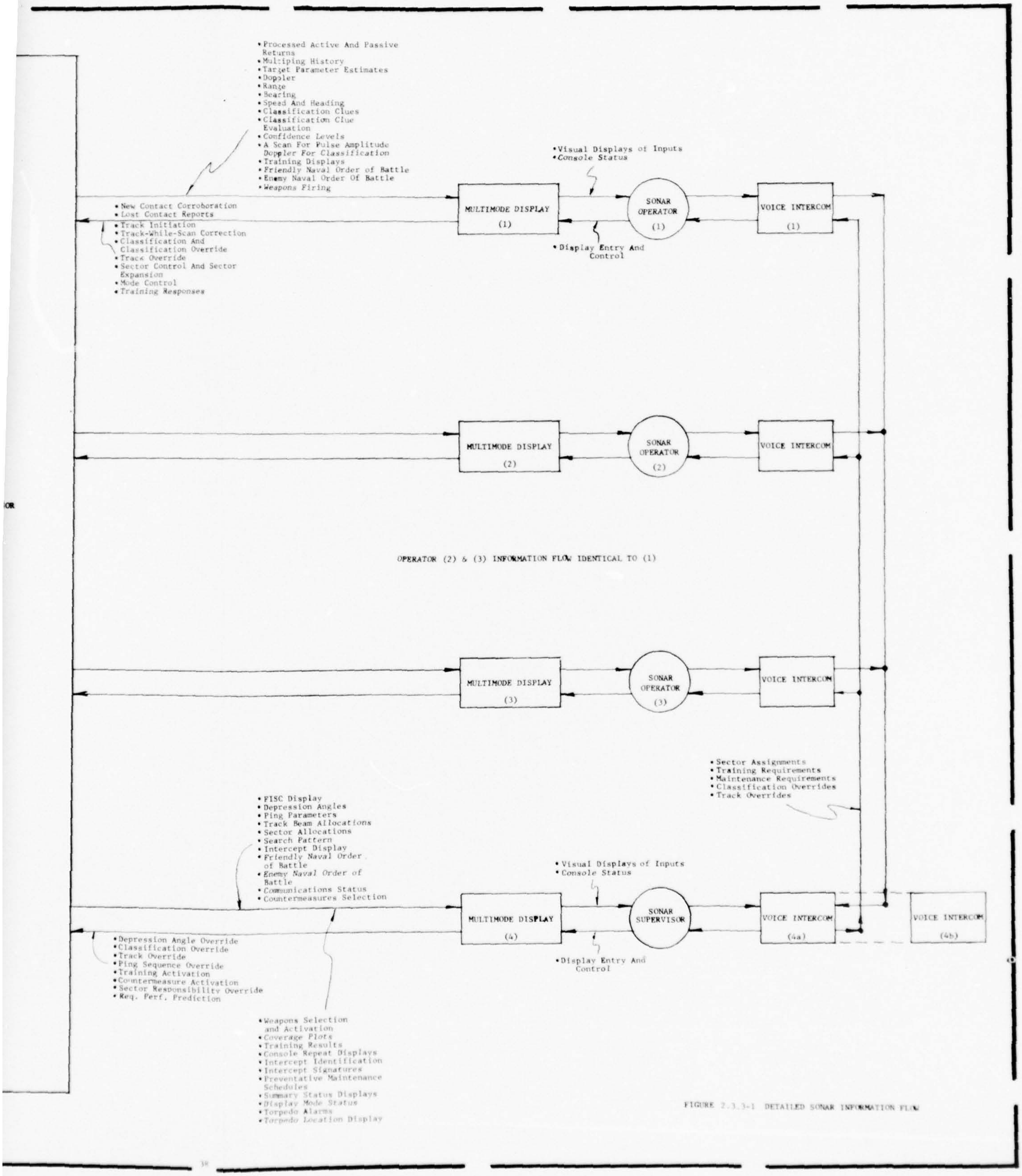


FIGURE 2.3.3-1 DETAILED SONAR INFORMATION FLOW

FIGURE 2.3.3-2 SONAR INTERFACE INFORMATION FLOW

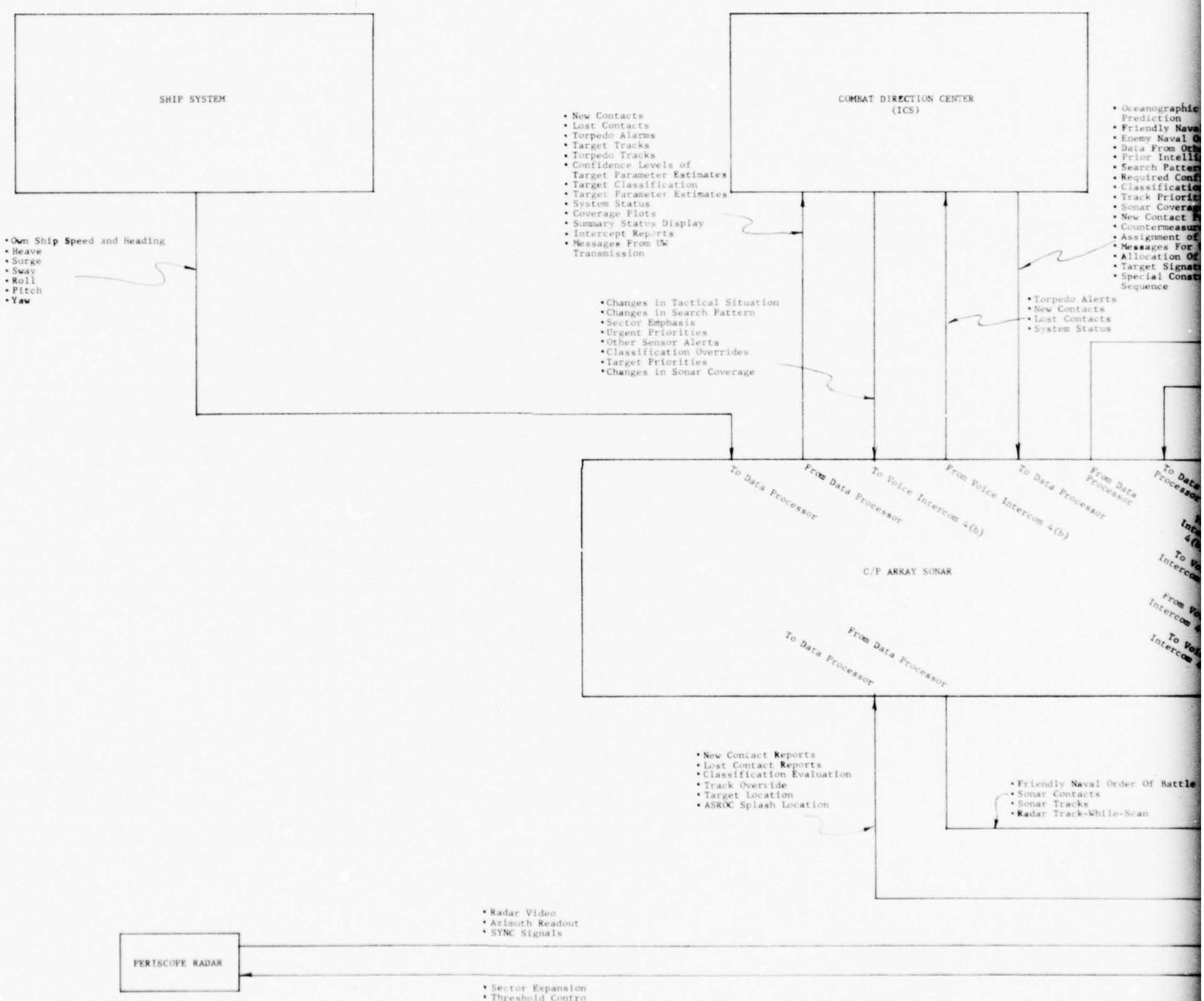
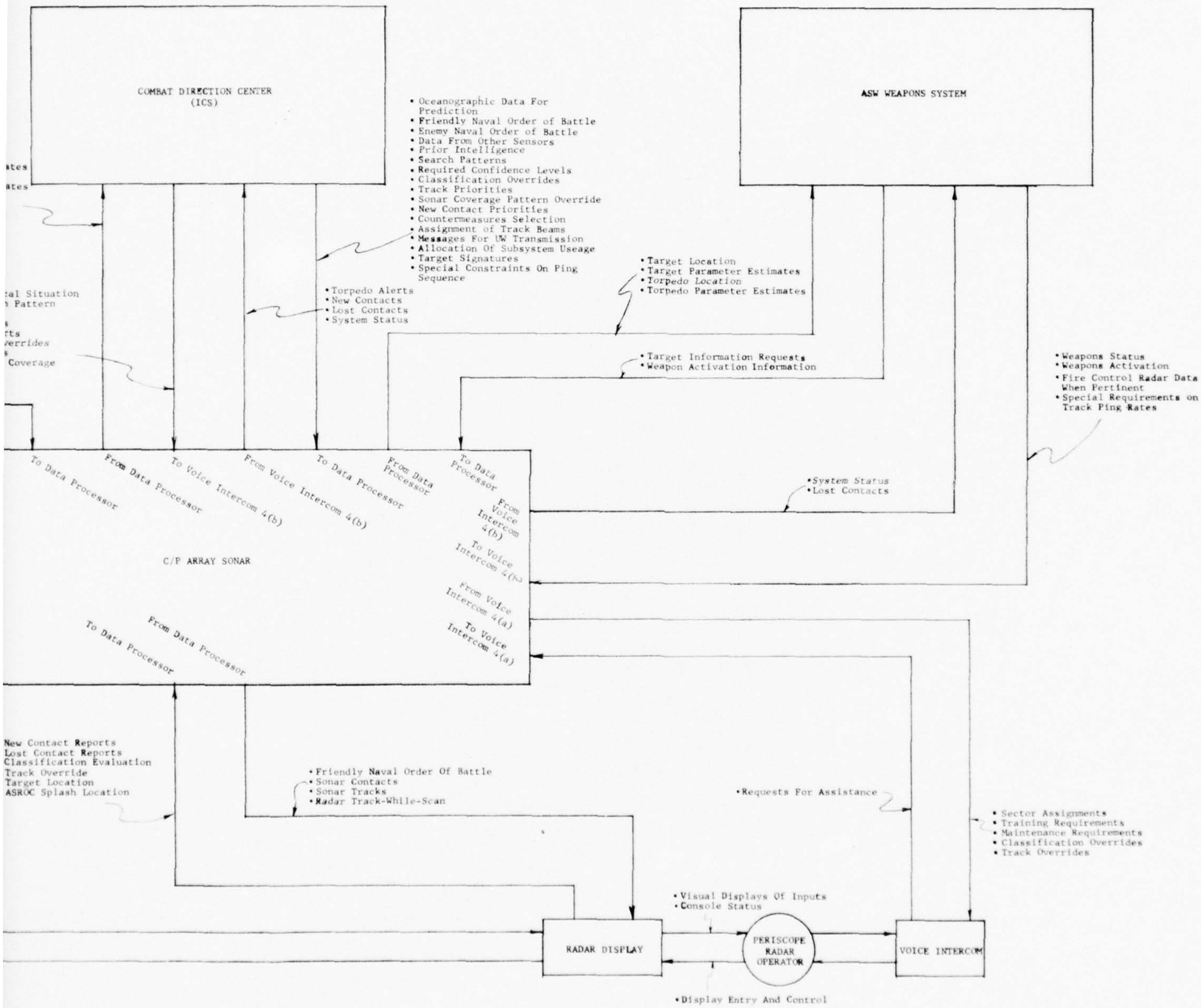


FIGURE 2.3.3-2 SONAR INTERFACE INFORMATION FLOW



TRACOR Dwg. No. 63 RTM, 10/5/66.

2.3.3.2 Passive Subsystem (Figure 2.3.3-1)

a. Inputs

(1) Normalization Constants. For noise equalization on all beams.

(2) Required Integration Periods.

(3) Required Depression Angles.

b. Outputs. Integrated energy outputs on all beams.

2.3.3.3 Torpedo Detection Subsystem and Acoustic Countermeasures (Figure 2.3.3-1)

a. Inputs. Countermeasures, activation and control.

b. Outputs. High closure rate alarms from active, passive, and special purpose equipments.

2.3.3.4 Acoustic Intercept Subsystem (Figure 2.3.3-1)

a. Inputs. Stored signature information for the identification of intercepted signals.

b. Outputs. Output of the reception of intercepted active acoustic transmissions.

2.3.3.5 Acoustic Communications Subsystem (Figure 2.3.3-1)

a. Inputs. Buffered outgoing messages.

b. Outputs. Incoming messages for EDP buffering.

2.3.3.6 Automatic Fault Isolation and Self-Check (FISC) (Figure 2.3.3-1)

In this subsystem function, fault indications from equipment racks are fed to the data processor, where they are scanned. The data processor, in turn, supplies fault circuit interrogation signals to the fault indication circuitry in each equipment module.

2.3.3.7 Acoustic Performance Prediction (Figure 2.3.3-1)

The functional block for acoustic performance prediction describes those sensors which are used to derive acoustic performance prediction by the data processor, since performance prediction is a software problem. Information will be derived from at least a bathythermograph and fathometer. The data processor will, in turn, interrogate these sensors in order to provide new performance prediction information.

2.3.3.8 System Control (Figure 2.3.3-1)

Based on performance prediction, the data processor can provide to the system control circuitry throughout the C/P Array Sonar optimum depression angles of the search and track beams, transmit beamwidths, ping sequences, types of signals to be transmitted, allocation of the track beams to targets, and subsystem operating schedules. In turn, from the system control circuitry, throughout the C/P Array Sonar System, the data processor must be given the current system control parameter status, i.e., depression angles, beamwidths, track beam orientation, and ping sequence.

2.3.3.9 Training (Figure 2.3.3-1)

Training is assumed to consist of replays of stored tapes consisting of multi-ping returns of live sonar data. In addition, stored tapes may be provided which will provide for programmed instruction training. The data processor, in turn, provides information to activate and control these training tapes. These tapes provide training instruction for sonar operator on how to operate the Sonar System.

2.3.3.10 Periscope Radar (Figure 2.3.3-2)

The periscope radar will feed radar video, antenna position, and range timing signals into a radar display and will

receive from the radar display sector control and threshold control signals.

The radar display provides the periscope radar operator visual displays of the radar inputs and information about the radar display console status. The periscope radar operator, in turn, controls the periscope radar through the periscope radar display console, and enters into the display unit information on new contacts, lost contacts, classification evaluation, track overrides, target location and ASROC splash location for subsequent transmission to the C/P Array Sonar Data Processor.

The periscope radar operator can communicate via voice intercom with the sonar supervisor, receiving sector coverage assignments, training requirements, maintenance requirements, classification overrides, and track overrides from the sonar supervisor.

2.3.3.11 Sonar Operator (Figure 2.3.3-1)

a. Digital Outputs. The sonar operators communicate with the data processor via the multimode display where they receive visual displays of inputs from the subsystems and information about the multimode display console status. In turn, they enter information to the data processor exercise system control via the multimode display. Each operator provides the following types of information to the data processor.

(1) New Contact Corroboration. It is assumed that the computer exercises automatic detection procedures, but that new cont·cts are corroborated by the operator and sent back into the computer.

(2) Lost Contact Reports

(3) Track Initiation

(4) Track-While-Scan Correction. It is possible that a maneuvering target may become discontinuous and corrections may be entered via the multimode display to connect track segments.

(5) Classification and Classification Override. It is expected that some degree of classification clue extraction and clue analysis will be performed in the data processor, but the operator will also have opportunity to do both of these functions.

(6) Track Override

(7) Sector Control and Sector Expansion

(8) Mode Control, i.e., Active Search, Active Track, Passive Search, Passive Track

(9) Training Responses

b. Digital Inputs. The sonar operator receives from the data processor the following information:

(1) Processed Active and Passive Signals.

(2) Multiping History (up to at least 6 pings).

(3) Target Parameter Estimates of Doppler, Range, Bearing, Speed and Heading, Classification Clues, Classification Clue Evaluation, and Confidence Level on Target Parameter Estimates.

(4) A-Scan amplitude and doppler information (in some sonar modes) to assist in target classification.

(5) Training Displays.

(6) Friendly Naval Order of Battle in order that friendly ships may be separated from the contacts displayed.

(7) Enemy Naval Order of Battle in order that already detected enemy ships and submarines may be identified on the console.

(8) Weapons Firing Information in order that friendly weapons be separated from the display of contacts on the multimode display.

c. Intercom. The sonar operator can communicate with the sonar supervisor via a voice intercom where he can receive sector assignments, training requirements, maintenance requirements, classification overrides, and track overrides; and the

operator can request assistance from the sonar supervisor.

2.3.3.12 Sonar Supervisor Information Flow

The sonar supervisor is primarily concerned with the control and monitoring functions of the C/P Array Sonar and with fault isolation and self-check.

a. Digital Outputs. The sonar supervisor provides to the computer the following information:

(1) Depression Angle Override. Special requirements for coverage would demand that the depression angles be used which are not optimized, for example, to area of coverage annulus.

(2) Classification Override.

(3) Track Override.

(4) Ping Sequence Override. Special conditions may require that the ping sequence be changed or that the active mode be switched off.

(5) Training Activation.

(6) Countermeasure Activation. In response to requests from the Combat Direction Center.

(7) Sector Responsibility Overrides. To the sonar operators.

(8) Requests for Performance Prediction.

b. Digital Inputs. The sonar supervisor receives the following information from the computer:

(1) Fault Isolation and Self-Check Display

(2) Depression Angles

(3) Optimum Ping Parameters

(4) Track Beam Allocations

(5) Sector Allocations

(6) The Current Search Pattern Defined From The Combat Direction Center

(7) Display of Intercepted Signals

(8) Friendly Naval Order of Battle

(9) Enemy Naval Order of Battle

(10) Communications Status on the Acoustic Communications Subsystem

(11) Countermeasures Selection Requirements From The Combat Direction Center

(12) Weapon Selection and Activation From The Combat Direction Center

(13) Coverage Plots. Plots of the coverage provided by the C/P Array Sonar and provided by the Acoustic Performance Prediction Subsystem.

(14) Training Results

(15) Console Repeat Displays. The supervisor should be able to see the displays currently on each of the operator's consoles.

(16) Intercept Identifications

(17) Intercept Signatures

(18) Preventive Maintenance Schedules

(19) Summary Status Displays

(20) Display Mode Status

(21) Torpedo Alarms

(22) Torpedo Location Display

c. Intercom. In addition to the voice communication with the sonar operators and the periscope radar operator, it is assumed that the sonar supervisor has a voice intercom (Figure 2.3.3-2), for communication with the Combat Direction Center and the ASW Weapons System.

The sonar supervisor will provide by voice to the Combat Direction Center information on torpedo alerts, new contacts, lost contacts, and system status. He will receive from the Combat Direction Center changes in the tactical situation,

changes in the search pattern, sector emphasis, urgent priorities, other sensor alerts, classification overrides, target priorities, and changes required in sonar coverage. This is not meant to imply that none of this information is interfaced via the data processor, but that the information may be of sufficient urgency to require voice back-up.

The sonar supervisor can provide to the ASW Weapon System urgent changes in system status and information on lost contacts. He would receive from the ASW Weapons System, weapons status, weapons activation, fire-control radar data when pertinent for corroboration of sonar contacts, and special requirements on track ping rates.

2.3.3.13 System Interface Information Flow (Figure 2.3.3-2)

a. Ship System. Signals must be received from the Ship's System in order to provide beam steering and stabilization. These signals would consist of own ship's speed and heading, heave, surge, sway, roll, pitch, and yaw. No information is fed to the Ship System from the C/P Array Sonar.

b. Combat Direction Center. The entire sonar system operates to satisfy the requirements of the Combat Direction Center, and receives from the Combat Direction Center and its associated data base and data processor the following information:

(1) Oceanographic Data for Performance Prediction

(2) Friendly Naval Order of Battle

(3) Enemy Naval Order of Battle

(4) Data From Other Sensors in order to corroborate sonar contacts.

(5) Prior Intelligence About Submarine Activity in the Search Area

(6) Search Patterns Required by the Mission

(7) Required Confidence Levels. On detection, classification and other target parameters.

(8) Classification Overrides. When the Combat Direction Center has information that sonar classification is erroreneous.

(9) Track Priorities

(10) Sonar Coverage Pattern Override. When the normal coverage pattern must be deviated from in order to satisfy a tactical exigency.

(11) New Contact Priorities

(12) Countermeasures Selection

(13) Assignment of Track Beams to Specific Targets

(14) Messages for Underwater Acoustic Transmission

(15) Allocation of Subsystem Usage, i.e., Active or Passive

(16) Target Signatures. Stored target signatures for intercept analysis from the Combat Direction Center data base.

(17) Special Constraints on Ping Sequence

The Combat Direction Center, in turn, receives in digital form via the Combat Direction Center Displays, the following information from the C/P Array Sonar:

(1) New Contacts

(2) Lost Contacts

(3) Torpedo Alarms

(4) Target Tracks

(5) Torpedo Tracks

(6) Confidence Levels on Target Parameters

(7) Target Classification

(8) Target Parameter Estimates

(9) System Status

(10) Coverage Plots

(11) Summary Status Plots

(12) Intercept Reports

(13) Messages Derived from Underwater Acoustic Transmission

c. ASW Weapons System. The ASW Weapons System derives fire-control information from the search and track beams of the C/P Array Sonar. It receives from the data processor target locations, target parameter estimates, torpedo locations, and torpedo parameter estimates. It provides to the C/P Array Sonar data processor target information requests and weapons activation information.

2.3.4 Man-Machine Information Flow Charts

The Man-Machine Information Flow Charts are derived from the information flow charts discussed in the above paragraphs of this section.

The information flow charts contained herein primarily pertain to sonar operators and their supervisor in relation to each other. In addition, their general relationship to the Combat Direction Center and the ASW Weapons System through the Voice Intercommunications System is also depicted, but in less detail. Information Flow Charts have been prepared for the following four modes: Active Search, Active Track, Passive Search/Passive Track, Control and Monitor. Each of the five information flow charts show the following:

a. Sonar Mode

b. Sonar Operator (or Supervisor) Functions

c. Input Information to Operator (or Supervisor)

d. Output Information to Operator (or Supervisor)

e. Flow Lines to and from Operator (or Supervisor)

f. Flow Lines Between Operator (Supervisor) and Sonar Display

g. Flow Lines Between Sonar Display and ADP

h. Flow Lines Between Supervisor and Operators through Intercom System

i. Flow Lines Between Supervisor and CDC and ASW System through the Intercom System

The following paragraphs discuss, in detail, the individual, information flow charts.

2.3.4.1 Man-Machine Information Flow Chart: Active Search Mode (Figure 2.3.4-1)

In the Active Search Mode, the primary operator functions are: Search, Detect Track, Enter Track, and Update Track (Manual). The input information to be displayed to the operator is subsumed under 20 categories and the output information required from the operator is 17 categories. It is assumed that these estimates of informational categories are required for performing the Active Search Mode Functions by the Sonar Operator. (Intercom functions and categories of information are not detailed on any of the charts, but it is assumed at present these categories will be similar to the operator functional input and/or output categories.)

2.3.4.2 Man-Machine Information Flow Chart: Active Tracking Mode (Figure 2.3.4-2).

In the Active Tracking Mode, the primary operator functions are: Automatic-Coarse Tracking, Semi-Automatic Tracking, Automatic-Fine Tracking, and Manual Tracking. The input information to be displayed to the operator has been subsumed under 27 categories and the output information required from the operator is 12 categories. It is assumed that these estimates of informational categories are required for performing the Active Tracking Mode Functions by the Sonar Operator.

FIGURE 2.3.4-1 MAN-MACHINE INFORMATION FLOW CHART: ACTIVE SEARCH MODE

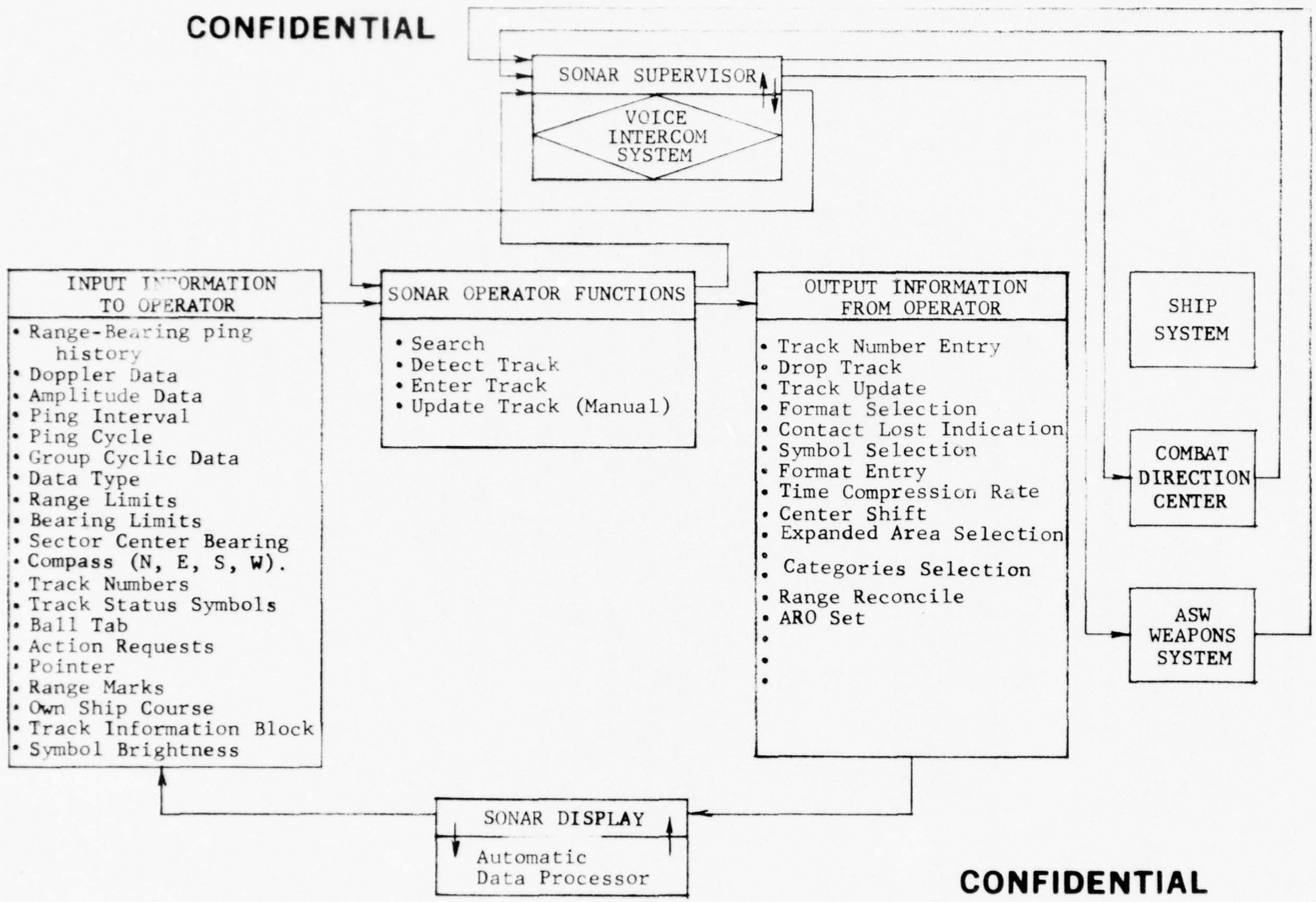


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FIGURE 2.3.4-2 MAN-MACHINE INFORMATION FLOW CHART: ACTIVE TRACKING MODE

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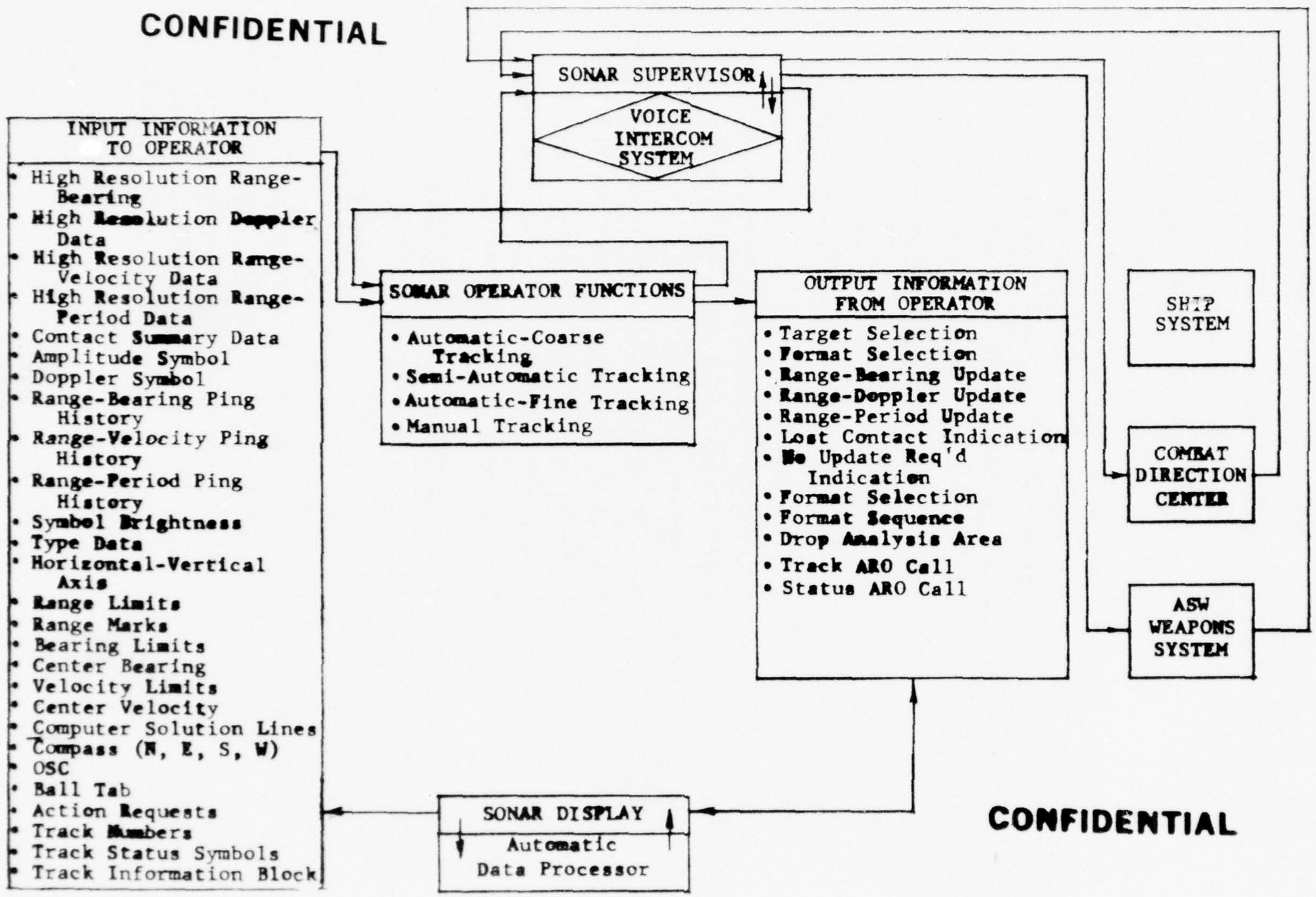

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2.3.4.3 Man-Machine Information Flow Chart: Passive Search/ Passive Track Modes (Figure 2.3.4-3)

In the Passive Search/Passive Track Modes, the primary operator functions are: Detect Targets, Enter Targets, Override Automatic-Target-Follower, and Monitor Current Tracks. The input information to be displayed to the operator has been classified under 13 categories and the output information required from the operator is 10 categories. It is assumed that these estimates of informational categories are required by sonar operators for performing the Passive Search/Passive Track Modes functions.

2.3.4.4 Man-Machine Information Flow Chart: Control Mode, Supervisory (Figure 2.3.4-4)

In the Control Mode, Supervisory, the primary supervisory functions are: Control Sonar Operations and Control Sonar Settings, Activate Performance Predictors to Sensors. The input information to be displayed to the supervisor has been classified under 22 categories and the output required from the operator is 15 categories. It is assumed that these estimates of informational categories are required by sonar supervisors for performing the Control Mode Function, Supervisory.

2.3.4.5 Man-Machine Information Flow Chart: Monitor Mode, Supervisory (Figure 2.3.4-5)

In the Monitor Mode, Supervisory, the primary supervisory functions are: Fault Detect, Fault Isolate, Check Equipment Tolerances, and Check Operator Performance Levels. About six general categories of input information are needed by the supervisor and probably four general categories of output information are provided by the supervisor in performing his functions in the Monitoring Mode.

FIGURE 2.3.4-3 MAN-MACHINE INFORMATION FLOW CHART: PASSIVE SEARCH/PASSIVE TRACK MODE

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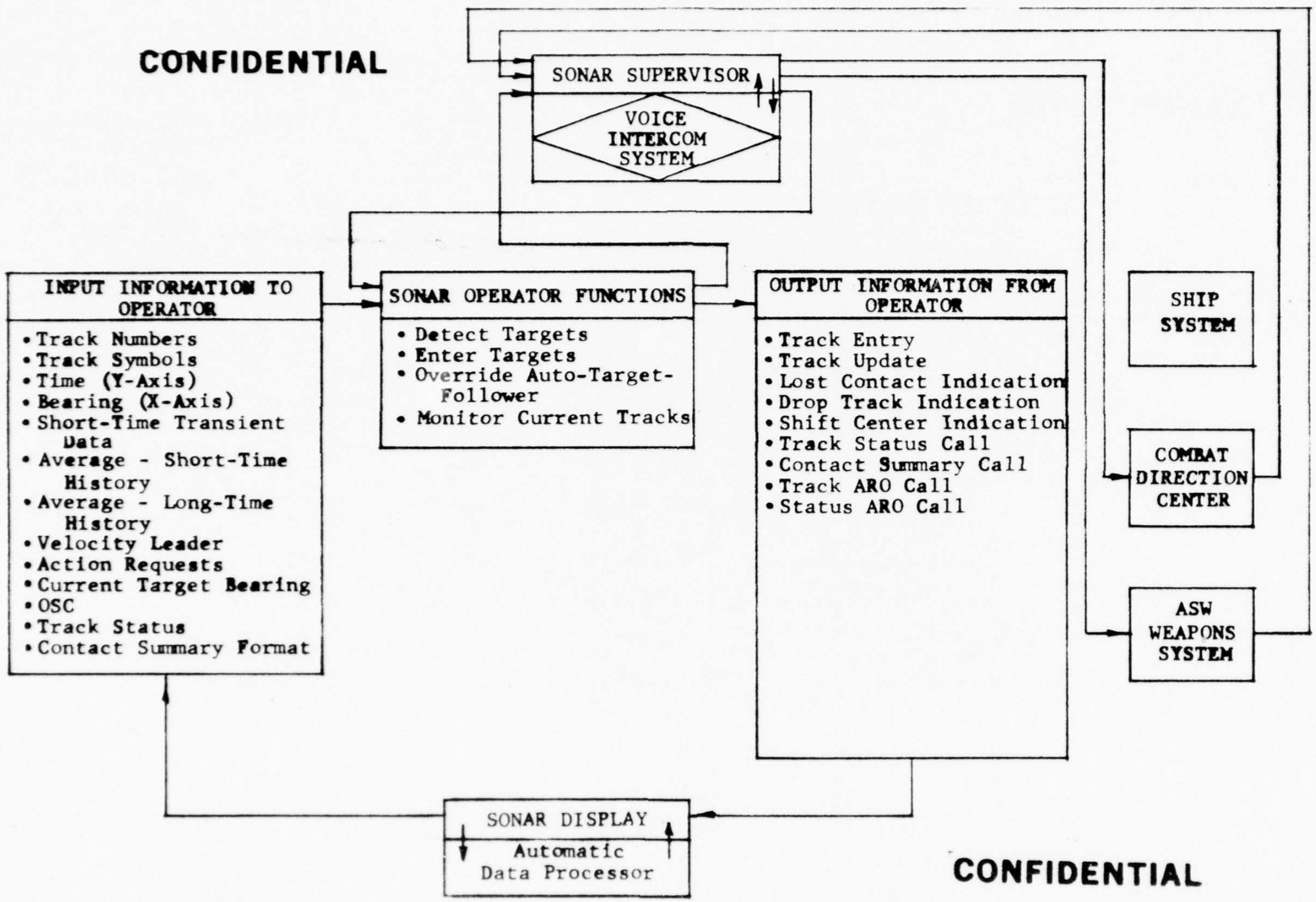

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FIGURE 2.3.4-4 MAN-MACHINE INFORMATION FLOW CHART: CONTROL MODE (SUPERVISORY)

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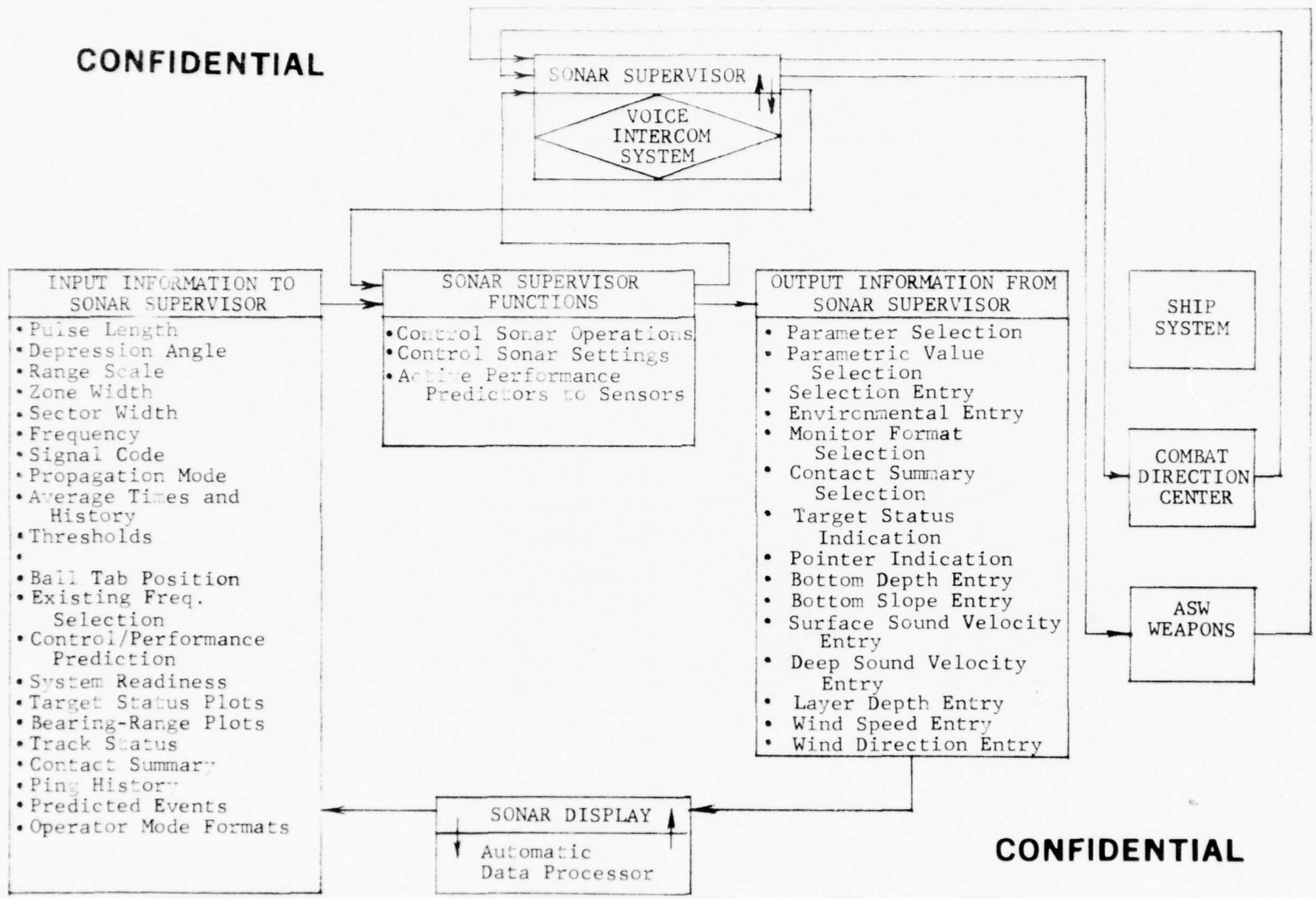

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FIGURE 2.3.4-5 MAN-MACHINE INFORMATION FLOW CHART: MONITOR MODE (SUPERVISORY)

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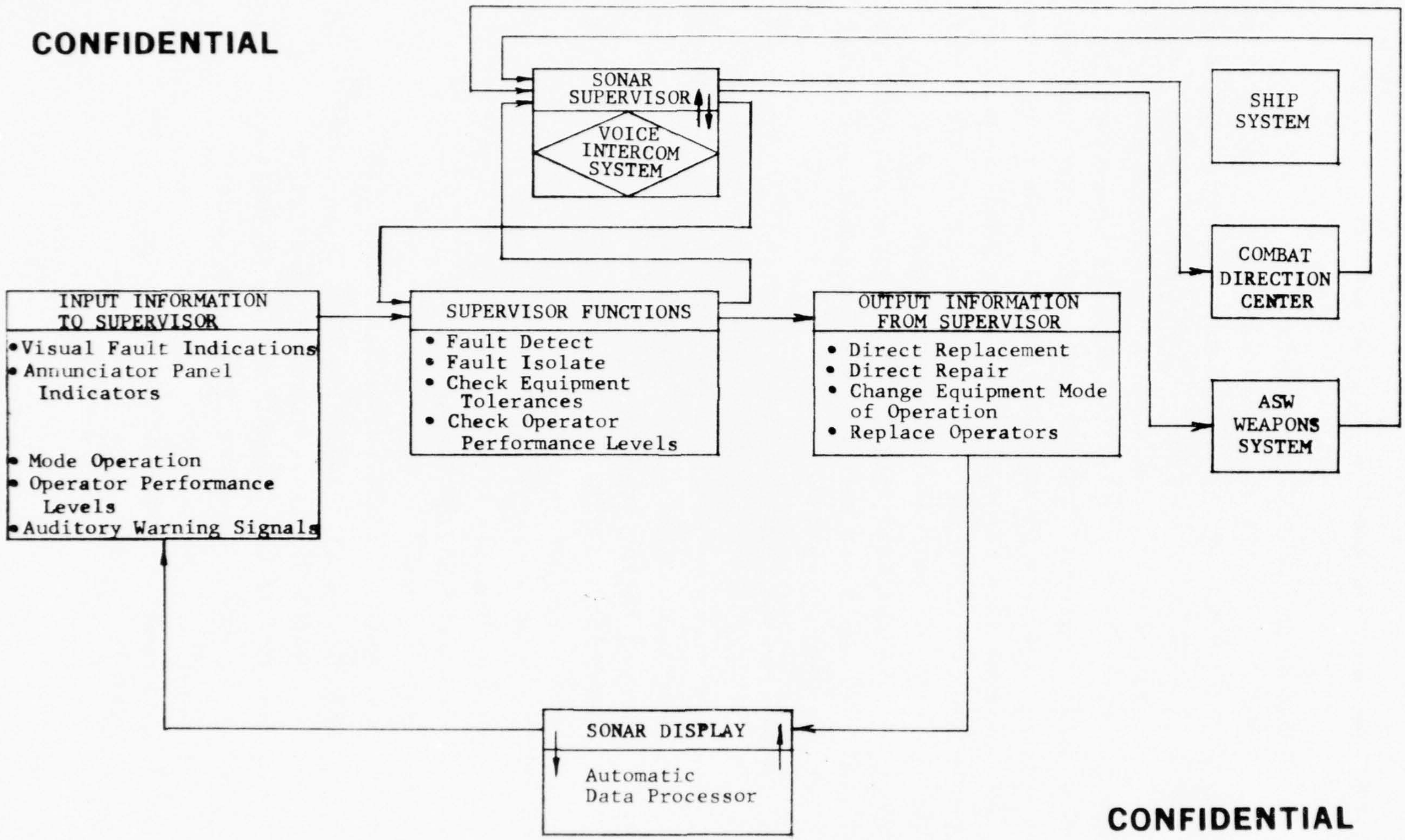

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2.4 Human Factors Trade-off Studies

In any complex and high capacity system, the question arises as to which functions should be made automatic and which are better left to a human operator. Experiments can be conducted after much hardware has been built which will settle these uncertainties with a high probability that the operationally best method will be found. However, this can be expensive and time consuming. The more of these issues which can be resolved in the early stages of a development by analytical means, the less experimental hardware will have to be built and the fewer tests will have to be run. At the present stage of the C/P Array sonar development only the grossest sort of analyses can be conducted, but these can serve as the basis for more searching studies farther down stream.

2.4.1 Trade-off's Considered

Preliminary trade-off studies have been conducted for the following modes of operation with the C/P Array sonar:

1. Fully Automatic Target Tracking vs. Manual Target Tracking.
2. Semi-Automatic Target Tracking vs. Manual Target Tracking.
3. Fully Automatic Target Tracking vs. Semi-Automatic Target Tracking.
4. Automatic Threshold Control vs. Manual Threshold Control.
5. Automatic Classification Clue Extraction vs. Manual Classification Clue Extraction.
6. Automatic Classification Clue Evaluation vs. Manual Classification Clue Evaluation.
7. Multimode Display vs. Single Operator Functional Displays.
8. Automatic System Control vs. Manual System Control.

These modes of operation were selected because they are considered to be the most critical as related to mission performance by the sonar system. The modes selected, therefore, are critical and representative but not exhaustive for this preliminary study.

2.4.2 Methodology

In comparing alternate ways of performing various functions an attempt has been made to assess both the relative performance characteristics and the comparative costs which associate with the competitive systems. Costs are broken down into operator costs and machine costs, while performance is subdivided into accuracy, speed, capacity, and reliability.

In the manual system, operator costs can be expected to be high because more operators with more training and more display equipment will generally be required. In the automatic system, computer costs may be high since more sophisticated data processors with larger memories may be required. A first-cut attempt is made in the following sections to assess these costs for the competitive systems listed in Section 2.4.1.

In making the cost and performance comparison between systems, it is assumed in all cases that the capacity of competitive systems is equal. Thus, the operator and computer costs are for systems of equal capacity. Performance accuracy and speed, on the other hand, will be the best achievable within the current state-of-the-art in the case of the automatic computer, whereas with the manual system, it will be the best that can be expected of a well-trained enlisted operator working with state-of-the-art displays in a wartime environment.

The reliability of the automatic system is the adjudged probability that the equipment functions in the manner it was designed to function. The reliability of the manual system is the probability that the operator functions

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without error (within his accuracy limitations) in operating controls, reading displays, making calculations, and communicating with other parts of the system.

2.4.3 Criteria Used in Trade-off Studies

The final measure of effectiveness in comparing alternate means of performing any function in an ASW System is the result in terms of submarines sunk. But the time and money which would be consumed in implementing and testing all alternative systems against this measure would be prohibitive, so some less ambitious method of evaluation must be used.

In this preliminary comparison of alternatives, only the cost and effectiveness of performing a subject function are compared. It is tacitly assumed that any improvement in the performance of the function will be directly reflected in the number of submarines sunk. Furthermore, the various function performance rating factors are assumed to have an equal effect on overall system performance. Thus, the accuracy with which a function is performed is assumed to be of equal importance to the speed. And all performance factors are assumed to have an importance equal to that of cost.

In view of the grossness of these assumptions, only a large difference in the "score" of competitive methods can be interpreted to be significant. In the absence of such a large difference, further analysis will ultimately be required to establish confidently the relative importance of the various rating factors.

In the comparison of alternate modes which follows, one mode has in every case been established as the reference mode (the manual mode) and the other mode (automated) compared to it in the two cost and four performance categories which have been established. Scoring in each category is one the basis of:

+3 Best Performance or Least Cost

+2 Considerably Better Performance or Lesser Cost

+1 Slightly Better Performance or Lesser Cost

0 Approximately Equal Performance or Cost

-1 Slightly Poorer Performance or Greater Cost

-2 Considerably Poorer Performance or Greater Cost

-3 Poorest Performance or Greatest Cost

The score for each mode is obtained merely by arithmetically summing the individual scores in the six categories. The larger the positive score, the greater the superiority that mode is presumed to have over its competitor. The assumption is made that the categories are independent of each other.

2.4.4 Trade-off Study Results

The results of the analyses of the eight competitive pairs are shown in Table 2.4.4-1. It will be noted that the best case is made for Fully Automatic Tracking against Manual Tracking. However, Fully Automatic Tracking is only marginally better than Semi-Automatic Tracking.

In all other cases (except Semi-Automatic Tracking vs. Manual Tracking), the difference is also marginal. In general automatic operation scores higher than manual operation, but Threshold Control is an exception. Automatic Threshold Control was found to be somewhat inferior to Manual Control.

2.4.5 Trade-off Study Summary

Only preliminary conclusions can be drawn at this time, but it appears to be preferable to perform most functions automatically with the aid of a computer rather than manually. System performance in the automatic system is in most cases

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Table 2.[illegible]-1 HUMAN FACTOR PARAMETRIC TRADE-OFF EVALUATIONS

MODES UNDER COMPARISON	SYSTEM COST		SYSTEM PERFORMANCE				SYSTEM SCORE
	Operator	Machine	Accuracy	Speed	Capacity	Reliability	
Fully Automatic Tracking No Additional Operators Least Squares-Curved Course Solution	Three fewer operators. Much cheaper. +3	Slightly greater memory. Slightly more expensive. -1	Much more accurate. +3	Much faster calculation. +3	Capacities equal by definition. 0	Operable slightly less of ten. 0	+8
Semi-Automatic Tracking One Additional Operator Least Squares-Straight-line Course Solution	Two fewer operators. Considerably cheaper +2	Slightly greater memory. Slightly more expensive. -1	Considerably greater accuracy. +2	Much faster calculation. +3	Capacities equal by definition. 0	Operable slightly less often. Within tolerances slightly more often. 0	+6
Fully Automatic Tracking No Additional Operators Least-Squares Curved Course Solution	One fewer operators. Slightly cheaper. +1	No significant difference in memory requirement. 0	Slightly more accurate. +1	No significant difference in speed. 0	Capacities equal by definition. 0	No significant difference in reliabilities. 0	+2
Automatic Threshold Control Threshold held at fixed level with respect to omnidirectional noise over fixed time interval.	Same number of operators. 0	Slight increase in memory requirement. -1	Will hold a specified threshold more accurately except for slow response. 0	Slightly slower in response to sudden changes in background noise. -1	Capacities equal by definition. 0	Slightly poorer reliability. -1	-3
Automatic Classification Clue Extraction Doppler Wake Depth Image Target Noise No Additional Operators	Three fewer operators. Much cheaper. -3	Greater increase in memory. Much greater cost. +3	Better in doppler and depth image. Poorer in wake and noise. 0	Extracts clues simultaneously. Much faster. +3	Capacities equal by definition. 0	Considerably poorer reliability. -2	+1
Automatic Classification Clue Evaluation Course and Speed Doppler Wake Depth Image Target Noise No Additional Operators	One fewer operators. +1	Slightly greater memory. Slightly more expensive. -1	About equal in accuracy. 0	Much faster evaluation. +3	Capacities equal by definition. 0	About equal in reliability. 0	+3
Multimode Display	Many fewer operators. +3	No increase in memory. 0	About equal in accuracy. 0	Slight decrease in speed. -1	Capacities equal by definition. 0	About equal in reliability. 0	+2
Automatic System Control	Probability no fewer operators. 0	Slight increase in memory. -1	Slightly greater accuracy. +1	About equal in speed. 0	Capacities equal by definition. 0	Considerably more reliable. +2	+2

Note: All scorings are relative to manual mode.

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somewhat superior because increased computer costs under automation are generally outweighed by the requirement for fewer operators under automation which increase costs under a non-automated system.

With the C/P Array Sonar, the human operator can expect to play the role of decision maker and monitor. He will select search constants such as frequency, search limits, and ping sequencing and he may select echo threshold. He will monitor the automatic target detection display, the automatic tracking solutions, and the automatic target classification, but he may on occasion decide to override them. He will monitor operation of the entire system to guard against malfunction. Only in the event of failure of some portion of the automatic system will he perform the functions of detection, classification, or tracking.

The operator's displays and controls must be those necessary for his role of decision maker and monitor. The extent to which he must be provided with functional displays for his back-up role will require further study and analysis.

3. CONCLUSIONS

The conclusions which follow are derived from the performance of the task stated in the contract from NEL to TRACOR.

3.1 Conclusions

The following conclusions are based on the results obtained in studying from a Human Factors viewpoint the C/P Array System.

a. There is a wide range of information categories to be processed by sonar operators in the several operating modes. Available state-of-the-art human factors studies, (as shown by the bibliography titles) indicate that high resolution, symbologies, brightness, doppler movement discrimination, and target classification have been studied for sonar as well as for radar systems. Available studies as inferred from titles of articles do not indicate that ping histories, fault detection, acceptance of transient inputs, and handling of environmental parameters have had as intensive study as the other parameters in the sonar situation.

b. A Human Factors Plan for the C/P Array sonar is both necessary and feasible for developing human factors design criteria to assure operability, supportability, and trainability of the C/P Array sonar system provided that a systematic approach is made in terms of type mission requirements. The TRACOR study developed a proposed detailed plan for the accomplishment of this objective for the C/P Array sonar system.

c. A Task and Time Schedule and Planning Requirements were developed based on the Detailed Human Factors Plan. An estimate of a 2 man/year effort for 1.5 years would be required, assuming that a senior scientist project-experienced in Human Factors was available to direct the HF Program.

d. Categories of information required for system operation at four levels along with the directions of flow of such information were formulated and depicted as flow charts. Further study of information flow in terms of type mission/task flows were not analyzed in this report. Typical ASW personnel organization for the C/P Array System and its relationship to other ship systems were tentatively defined. It was found that many diverse categories of information must be handled by sonar operators and supervisors for system operation. This initial classification provides guidance for further study of operator and supervisor functions for system operation as well as for type mission/tasks.

e. Human Factors trade-off studies of parameters influencing the mannual vs. automatic control will probably provide the best system performance for less cost although not in the case of threshold control. A weighted scale was used to provide the preliminary trade-off analysis. These conclusions on trade-off's can be used to provide initial design guidelines for further analysis with a more sophisticated methodology.

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APPENDIX A

PARTIALLY ANNOTATED BIBLIOGRAPHY

APPENDIX A

PARTIALLY ANNOTATED BIBLIOGRAPHY

I. DISPLAY SYSTEMS

1. Anti-Submarine Warfare Systems Project Office, "Technical Development Plan for Conformal/Planar Array Sonar System, SS-048," S22-17X, CONFIDENTIAL, 1 April 1966.

This comprehensive document has as its objective, a presentation of those quantitative performance objectives necessary as a basis for orderly, logical program planning and management. Included in this report are sections on the functional block diagram, subsystem characteristics, associated system characteristics, reliability and maintainability plan, operability and supportability plan, test and evaluation plan, and personnel and training plan. Problem areas in the system are indicated.

2. Bureau of Naval Weapons, "Appendix: AN/SQS-26 Sonar," NavWeps Report 8561, Washington, D. C., CONFIDENTIAL.

3. BuShips, "Technical Manual for Data Display Group in NTDS," NavShips 94,976, Vol. 4, CONFIDENTIAL, 1 May 1964.

4. BuShips, "Technical Manual For Documentation Index and Bibliography For NTDS," NavShips 94,976, Vol. 5, CONFIDENTIAL, May 1964.

This document provides a composite bibliography of documents published on NTDS, and an index of major areas of work.

5. BuShips, "Technical Manual For Introduction To NTDS," NavShips 94,976, Vol 7, NTDS Library Vol. 1, CONFIDENTIAL, 1 May 1964.

This document describes what the NTDS is and how it operates in a general way. Operator functions are outlined.

6. Bureau of Ships, "Brief of the Proposed Technical Approach For An ASW Ship Integrated Combat System," (A Proposed New Advance Development Project) and an ASW Command and Control System, (A Proposed New Engineering Development Project), Washington, D. C., CONFIDENTIAL, Revised 23 October 1964.

7. Defense Documentation Center, "Display Systems, A Report Bibliography," AD-265 432, Alexandria, Virginia, UNCLASSIFIED.

This bibliography was prepared by ASTIA in response to frequent inquiries concerning specific types of displays, their application in various electronic systems, and related human engineering factors. A secret volume of this bibliography is published separately as AD-326 260.

8. ComCarDiv ONE, "NTDS Operations of Task Group 77.5, 1 August 1963 - 18 February 1964," CONFIDENTIAL, 19 February 1964.

9. Carrier Division TWO, "NTDS Evaluation Report, CONFIDENTIAL, 20 August 1964.

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11. FAAWTC, "Command and Staff Manual for the Naval Tactical Data System," CONFIDENTIAL, 1 June 1962.

12. FCPCP, "Naval Tactical Data System Command and Staff Manual," Manual M-5000, CONFIDENTIAL, 1 July 1963.

13. Fleet Computer Programming Center Pacific, "Introduction to the Naval Tactical Data System," Manual M-5007, CONFIDENTIAL, 1 December 1964.

14. General Electric Company, Heavy Military Electronics Division, "AN/SQS-26(AX) Sonar Detecting and Ranging Set, Trainees Workbook," Report ECR-1850, GET 19-65-1, CONFIDENTIAL, March 1965.

This document was produced as a training document for the AN/SQS-26(AX) System. It contains training information relative to: the purpose and use of the equipment; four-mode flow diagrams; PPI range sweep generation, B-scope range sweep generation and A-scan range sweep generation.

15. General Electric Company, Heavy Military Electronics Division, "AN/SQS-26(AX), Sonar Detecting and Ranging Set Block Diagram Book," Technical Report ECR 1851, CONFIDENTIAL, March 1965.

This document was produced as a training aid to assist in the presentation of information relative to the AN/SQS-26(AX) Sonar Detecting System. The material contained in this document provides an understanding of the data block diagram flow in the AN/SQS-26(AX) System. The video and audio for tracking block diagrams describe how headphones, PPI and B-scope presentations are utilized.

16. General Electric Company, "Bibliography of GE Reports on AN/SQS-26," C-1386, (1964 and 1965).

17. General Electric Company, "Planar Array Sonar System," Report EH-88157, Syracuse, New York, CONFIDENTIAL, Various Dates (1965).

18. General Electric Company, "C/PAS Data Handling/Implementation, Interim Report C043-48003, Syracuse, New York, CONFIDENTIAL, 1 August 1966.

This study enumerates all control functions which may be under operator control. It is directed exclusively to active system.

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20. Navy Electronics Laboratory, "NEL Human Engineering Work on the Naval Tactical Data System," May 1956 through June 1958, by R. Coburn, Technical Memoranda 297, UNCLASSIFIED, 25 July 1958.

21. Navy Electronics Laboratory, "Characteristics of the ASW System for the Sea Hawk/AGDE," Technical Report, CONFIDENTIAL.

This document summarizes a feasible ASW System for the Sea Hawk/AGDE. Equipment configurations for the test and demonstration vehicle are contained in this docu nt useful as a guide in considering equipment that might be required for the C/P Array Experimental Ship System (ESS). AGDE System components are

described in terms of: 1) Sonar, 2) Tactical Coordination and Fire Control, 3) Radar, 4) Weapons. A functional block diagram is included which could be used as a model to produce a similar functional block diagram for the C/P Array Prototype Ship.

22. Navy Electronics Laboratory, "SEA HAWK Integrated Combat System, Third Level Functional Analysis Report Review Manuscript," NEL Technical Report, CONFIDENTIAL, February 1964.

This report is an NEL in-house statement, based upon contributions from seven navy laboratories. The description of an integration of ASW System functions, functional modules, facilities, and personnel is the essence of this report. This is a primary source document for human factors considerations that are applicable to the C/P Array Sonar System. The document states that the C/P Array Sonar Ship will have to have similar characteristics in order to meet ASW operational requirements. Thus, it is an excellent source upon which to base human factors assumptions in the absence of more specific information. Operators of the functional modules and the functional combat system are described in terms of "Position Descriptions" and specific responsibilities and duties are designated.

23. Navy Electronics Laboratory, "SEA HAWK Integrated Combat System: Third Level Functional Analysis, Summary Report as of 1 May 1964," Technical Memorandum 720, San Diego, California, CONFIDENTIAL, 9 September 1964.

24. Navy Electronics Laboratory, "ASW Ship Integrated Combat System, Developmental Model," Technical Report 3330-692, CONFIDENTIAL, 28 October 1964.

This document was intended to provide the primary guidance for the development of specifications for hardware implementation and associated computer programming for the Anti-Submarine Warfare Integrated Combat Control System. It defines the functional characteristics of a developmental model tactical Data Processing System for the ASW Ship, with integrated sensors and weapons. The ASW missions and tasks are described for the primary mission of Anti-Submarine Warfare. Functional descriptions of the Integrated Combat System are comprised of five parts as follows: a) Sensors, b) Ship Control and Navigation, c) Stabilization Sub-System, d) Weapons Systems, e) Combat System Operating Positions. The Combat System Operating Positions are described for each of the operating positions in the Combat System in terms of the following descriptions: 1) Functional Description, 2) Display, 3) Communication, 4) Description of Operations. This is a primary source document for human factors considerations as it contains mission and task information applicable to the C/P Array System.

25. Navy Electronics Laboratory, "Facility and Operational Plan for a Shore-Based Mock-Up of an Anti-Submarine Warfare Integrated Combat System," San Diego, California, CONFIDENTIAL, 2 November 1964.

26. Office of Naval Material, "Technical Development Plan SS-041, Surface Ship Sonar AN/SQS-26, S22-02," Washington, D. C., CONFIDENTIAL, 15 June 1965.

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28. Pittsburgh University, Department of Sociology, "Toward A Methodology For Establishing Command and Control System Display Requirements," by Richard Pomeroy, Jiri Nehnevajsa, Final Report, AD-467 503, Pittsburgh, Pennsylvania, UNCLASSIFIED, July 1965.

This report examines the general elements of a proposed methodology for the determination of display requirements in Tactical Command and Control Systems. Such a methodology is intended to serve as a guide to the integration of the complex technologies associated with the final design of a single display or display subsystem.

29. Remington Rand UNIVAC, "Naval Tactical Data System," PX1305, CONFIDENTIAL, June 1959.

An illustrated functional description of NTDS is presented. The tactical situation elements and requirements imposed on NTDS are itemized. Automated functions of combat direction are delineated. The equipment complex and tactical functions are described. Information transfer between fleet elements is discussed. Design philosophy concepts are also presented.

30. Remington Rand UNIVAC, "Preliminary Recommendations for Testing and Evaluation of the Naval Tactical Data System," Contract NObsr-63010; Spec. Report 1.

31. TRACOR, Inc., "Data Display System," by E. A. Tucker, et al., Final Engineering Report, CONFIDENTIAL, 27 April 1961.

32. TRACOR, Inc., "Proposed Sea Test Schedule For Passive Sonar Display System," by E. A. Tucker, et al., CONFIDENTIAL, 31 August 1961.

33. TRACOR, Inc., "Performance Comparison of the AN/SQS-23 and PAIR," Document Number 65-357-C, Technical Note (Revision), CONFIDENTIAL, 15 November 1965.

34. Underwater Sound Laboratory, "Operating The SQS-26 In An Ocean Environment," by T. G. Bell, USL 726, April 1966.

35. Underwater Sound Laboratory, "Handbook for AN/SQS-26 Sonar Performance Mission," by R. C. Chapman, USL 738.

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36. Hughes Aircraft Company, "Functional Requirements For A Multi-Mode Sonar Console," Final Report (FR) 66-11-81, Contract #N123(953)53350A, CONFIDENTIAL, 1 May 1966.

This report is a study which covers display requirements in all anticipated operating modes, display-operator interface, symbologies and display rates.

37. Human Engineering Labs, "Human Factors Engineering Design Standard for Missile Systems and Related Equipment," by Robert F. Chaillet, AD-623 731, Aberdeen Proving Ground, Maryland, UNCLASSIFIED, September 1965.

The purpose of the standard is to provide human factors engineering design principles and detailed criteria. The design principles are expressed as general rules applicable during system research and development programs, or as essential items to be considered during design, to insure the incorporation of sound human factors engineering practices. The detailed criteria consist of dimensions, ranges, tolerances and other specific data. The range of acceptable dimensions and other factors may be rather large in some cases.

38. Lear, Inc., "Whole Panel Control-Display Study, Vol. II, The Mark IV Control-Display System," by Max E. Olinger, Thomas E. Hainsworth, AD-266 341, Grand Rapids, Michigan, UNCLASSIFIED, July 1960.

A discussion is presented of a logical, step-by-step procedure to the design of a specific control-display system. As a result of the experimental evaluation and testing of each step, those modifications, refinements, and detail developments found necessary or desirable were incorporated into the method. After control-display requirements and display specifications were determined, they were converted into individual mockup displays and finally into a complete full-scale crew station mockup. Extensive documentation is included not only to substantiate the resulting control

display system, but also to provide an example for future crew station design. Appendices are also included describing several experimental studies which were conducted to define certain relationships and the boundaries of some of the control-display problem areas.

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40. Underwater Sound Laboratory, "Red Lighting vs. White Lighting on Sonar Operated Consoles," Preliminary Discussion, USL Technical Memorandum 905-51-65, by E. H. Howard, CONFIDENTIAL, 25 October 1965.

41. Wright Air Development Center, "A Functional Application of Anthropometric Data to the Design of the Workspace of PPI Scope Operators," by J. D. Coakley, I. T. Fucigna, and J. E. Barmack, TR-53-3, January 1953.

42. Wright Air Development Center, "Layout of Workspaces," by J. H. Ely, R. M. Thompson, and J. Orlansky, TR-56-171, UNCLASSIFIED, September 1956.

A. CONTROL DESIGN

43. Honeywell, Inc., "Compatibility of Display and Control," by Robert Gottsdanker and John Senders, AD-235 168, Minneapolis, Minnesota, UNCLASSIFIED, February 1959.

44. IBM Command Control Center, "Evaluation of Two Types of Manual Input Pushbuttons," by Sylvia M. Wassertheil, Federal Systems Division, Kingston, New York, AD-252 033, UNCLASSIFIED, November 1960.

This experiment was conducted to determine how various pushbutton designs would affect input speed and accuracy. Two pilot study pushbutton designs were chosen which should theoretically produce the greatest differences. There were no experimentally measurable differences.

45. Martin Marietta Corporation, "The Design of Operator Controls: A Selected Bibliography," by Frederick A. Muckler, AD-267 055, Baltimore, Maryland, UNCLASSIFIED, March 1961.

The purpose of this report is to present a bibliographic survey of research on critical variables in the design of operator controls. Major emphasis in selecting articles was placed on the problems of (1) Types of Manual Operator Controls, (2) Selecting Operator Controls, (3) Physical Dimensions of Operator Controls, (4) Inadvertent Control Operation and Control Coding, (5) Environmental Factors and Personal Equipment, and (6) Layout of Controls. Where pertinent, material has been added in the areas of (1) Skilled Operator Movement Characteristics and (2) Display-Control Relationships. Of prime interest was the physical characteristics of operator controls.

46. Navy Electronics Laboratory, "Variability in Sonar Target Tracking with Joystick and Two-Hand Control," by H. F. Sahlein, Technical Memorandum 224, CONFIDENTIAL, 13 November 1956.

47. Navy Electronics Laboratory, "A Comparative Study of Six Keyset Entry Units," by S. Webb, Report 902, UNCLASSIFIED, 18 February 1959.

48. Navy Electronics Laboratory, "Human Factors in Keyset Design," by W. A. Hillix and R. Coburn, Report 1023, UNCLASSIFIED, 22 March 1961.

49. Navy Electronics Laboratory, "Operator Performance on Miniaturized Decimal Entry Keysets," by L. E. Hufford and R. Coburn, Report 1083, UNCLASSIFIED, 4 December 1961.

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52. Remington Rand UNIVAC, "Naval Tactical Data System Tech Note 212: Functional Specifications For the Service Test Aircraft Data Entry Keyset," PX 1343-13, 11 February 1960.

53. Remington Rand UNIVAC, "Operational Requirements For The Service Test Navigation Keyset," PX 1343-12, CONFIDENTIAL, August 1960.

The Navigation Keyset proposes a means of manual entry of pertinent navigation data into the unit computer. The Universal Keyset was modified to perform this function. Manual entry is accomplished by giving

each of the Keyset buttons titles appropriate to the input function, and by defining computer response to action codes and data. This document defines the Navigation Keyset Inputs used.

54. Wright Air Development Center, "Design of Controls," by J. H. Ely, R. M. Thompson, and J. Orlansky, Technical Report 56-172, UNCLASSIFIED, November 1956.

This report provides a compilation of human engineering recommendations concerning various aspects of control selection and design. The main parts are: Selection of Proper Control, and General Considerations for Specific Controls.

55. Wright Air Development Center, "Man-Machine Dynamics," by J. H. Ely, N. M. Bowen, and J. Orlansky, Technical Report 57-582, UNCLASSIFIED, November 1957.

B. DISPLAY DESIGN

56. Air Force Special Weapons Center, "Human Factors Checklists for Test Equipment, Visual Displays and Ground Support Equipment," by R. L. Krummin and W. K. Kirchner, AFSWC-TN-56-12, Kirtland Air Force Base, New Mexico, UNCLASSIFIED, February 1956.

This report consists of a series of checklists intended as an aid in the human engineering analysis of general design features of certain types of equipment. The checklists can be used to identify human factors design deficiencies. The three checklists included in this document are: Human Factors Checklist for Ground Support Equipment, Human Factors Checklist for Test Equipment, and Human Factors Checklist for Visual Displays.

57. Boeing Company, "Comparative Evaluation of Display Techniques," by Erle W. Malone, EUR 417, CONFIDENTIAL, 12 December 1963.

58. Defense Documentation Center, "Data Display Study," by W. Stein, Final Report, EUR 413, Fort Monmouth, New Jersey, 1 February 1961.

59. FCPCP, "NTDS/WDE Mark II Display Precision Considerations in Tracking," by L. V. Broccoli, F. D. Cardamone, and T. M. Widing, Final Report 3044, CONFIDENTIAL, 18 June 1964.

60. Hughes Aircraft Company, "Data Display Group AN/SSA-23 (XN-1) Combat Information Central AN/SSQ-25 (XN-1)," Final Engineering Report, FTD 59-32, CONFIDENTIAL, June 1959.

This report contains a description of the developmental NTDS equipment and covers the major problems encountered. Some of the items discussed are operator fatigue, electro-luminescent lighting, track ball selection, panel layout and display symbology.

61. National Research Council, "Illumination and Visibility of Radar and Sonar Displays," by R. H. Brown, Publication 595, AD 220 665, Washington, D. C., UNCLASSIFIED, 1958.

The following areas are discussed: (1) operational requirements for CRTs and displays in relation to illumination problems, (2) methods for controlling ambient illumination, (3) display requirements imposed by visual factors, and (4) new techniques under development.

62. Navy Electronics Laboratory, "Report on Test Set 1.1 of the Experimental NTDS," Technical Memorandum 373, 19 November 1959.

63. Navy Electronics Laboratory, "Some Design Considerations for a Symbolic Cathode-Ray Tube for LORAD Detection Display Simulator," by P. M. Hamilton, Technical Memorandum 387, UNCLASSIFIED, 3 February 1960.

64. Navy Electronics Laboratory, "NTDS Display Development," CONFIDENTIAL, August 1963.

65. Navy Electronics Laboratory, "Multi-Mode Sonar Console and Passive Data Memory Unit," Spec. 3180-66-2, UNCLASSIFIED, February 1966.

Specification based in part on previous Hughes Study. Defines display rates, brightness, flicker constraints. Complete description of display characteristics in all operating modes.

66. Naval Research Laboratory, "Color Cathode Ray Tube Displays in Combat Information Centers," Final Report, AD-623 960 by D. C. Burdick, and L. M. Chauvette, J. Dules, Washington, D. C., UNCLASSIFIED, October 1965.

Some recent technological advancements with color in cathode ray tube (CRT) Displays. The continuing demand to present additional information more efficiently in command and control centers, and the introduction of stored information systems have stimulated renewed interest in color as a coding dimension. This study examines the human factors and engineering considerations as they relate to the central problem of the relative cost effectiveness of color given the present engineering state-of-the-art as compared to other combat

coding dimensions for combat information displays and concludes that: (1) the comparative ranking of color with other coding dimensions is high related to the task performed, (2) other situational factors greatly affect the value of color as a coding dimension, (3) there are perceptual problems involving the use of color, but techniques are available to enhance the value of color as a coding dimension, (4) the state-of-the-art for producing color CRT displays in encouraging, but only two tubes seem likely to have application in the near future, and, (5) monetary cost estimates have been difficult to obtain, but other more easily ascertained cost factors indicate that for some tasks color will be well worth the cost.

67. Ohio State University, Research Foundation, "Research on Display Variables," by William C. Howell, Jerry D. Tate, Final Report, AD-606 637, Laboratory of Aviation Psychology, Columbus, Ohio, UNCLASSIFIED, August 1964.

Three formal experiments were conducted on variables contributing to the accessibility, for human viewers of information in large-scale displays. The subject observed a tabular or spatial display containing both relevant and irrelevant events in randomly assigned positions. After a controlled period of inspection, he was required to report the location of relevant events; various S accuracy and latetal--DD latency scores were recorded. Major variables of interest were: duration of inspection, amount of relevant and irrelevant information, degree of irrelevancy, kind of irrelevancy, display format, and goodness of event

patterning. All results pointed toward two major conclusions: the subject increases accessibility through organization, at a peripheral level, of relevant information; storage of displayed information involves two distinct processes--one more central and permanent, the other more peripheral and temporary. Implications for display design are discussed.

68. Ohio State University, Research Foundation, "Information Input and Processing Variables in Man-Machine Systems: A Review of the Literature," by William C. Howell, George E. Briggs, AD-230 997, Laboratory of Aviation Psychology, Columbus, Ohio, UNCLASSIFIED, September 1960.

69. Rome Air Development Center, "Compendium of Visual Displays," Compendium 61-1, OFFICIAL USE ONLY, December 1961.

70. TRACOR, Inc., "The Design of a Psychophysical Experiment and the Development of the Experimental Materials to Assess the Scenics Display," by B. H. Deatherage, January 8, 1963.

71. TRACOR, Inc., "Design of a Psychophysical Experiment Using the USNEL Charactron Display," by B. H. Deatherage, Document No. 63-197-U, UNCLASSIFIED, 19 July 1963.

72. TRACOR, Inc., "Design of an Experiment to Assess the USNEL Charactron Display," by B. H. Deatherage, Document No. 63-300-U, UNCLASSIFIED, 20 December 1963.

73. TRACOR, Inc., "Display Analysis," by J. M. Young, Technical Note, 65-107-C, CONFIDENTIAL, 15 January 1965.

74. C. T. White, "The Significance of Form Discrimination In Navy Operations," in Form Discrimination as Related To Military Problems, J. W. Wolfeck and J. H. Taylor, eds., Publication 561, NAS-NRC, Washington, D. C., 1957, pp. 3-6.

C. PANEL LAYOUT

75. FCPCP, "Human Factors Study of Data Readout, Alerts, and General Purpose Function Codes," 1R2082, 7 June 1965.

76. FCPCP, "Human Factors Study of Data Readout, Alerts, and General Purpose Function Codes," Final Report 3064, 30 June 1965.

77. General Dynamics Corporation, "Command Control I, Multiple Display Monitoring II, Control-Display Spatial Arrangement," by Wesley C. Blair, Herbert M. Kaufman, AD-231 616, Electric Boat Division, Groton, Connecticut, UNCLASSIFIED, September 1960.

78. General Dynamics Astronautics, "An Improved Method of Panel Design," by Harold G. Wakeley, AD-457 799, UNCLASSIFIED, April 1963.

This paper discusses the problem of defining functionally related areas of display and control panels. A module design method currently in use is compared with the use of conventional enclosing lines.

79. National Research Council Committee on Undersea Warfare, "A Survey Report on Human Factors in Undersea Warfare," by R. C. Channell and M. A. Tolcott, Panel on Psychology and Physiology, CONFIDENTIAL.

80. Navy Electronics Laboratory, "Electroluminescence: A New Concept in Lighting and Information Display," by F. W. Smith and C. E. Cunningham, Technical Memorandum 280, UNCLASSIFIED, 4 April 1958.

81. Rome Air Development Center, "High Contrast Versus Standard Electroluminescent Panels on the Identification of Symbology," by J. Anthoney Ciuffini, and Edward F. Rizy, Final Report, AD-484 731, Griffiss Air Force Base, New York, UNCLASSIFIED, June 1966.

The objective of this study was to determine the applicability of high contrast to both the monostable and bistable class of electroluminescent (EL) displays. An experimental display environment simulating the conditions for a command and control display situation was established and subject response was recorded when numerics were displayed on both a high contrast and conventional electroluminescent display panel. Controls were placed on the experimental procedures to insure against any learning effects which might occur. A 'Forced Choice' instruction was imposed on the subjects, compelling them to guess, to reduce differences between subjects. The data were analyzed using two criteria, one statistically equivalent to perfect performance and the other requiring actually perfect performance. Results were compared and applied to the operational display environment.

82. Underwater Sound Laboratory, "Human Engineering Review of Preliminary Panel Layout Involving the SQS-26 (AX) Modification," Technical Memorandum 905-49-64, 2 September 1964.

III. INFORMATION PRESENTATION

83. Applied Psychological Services, "Information Transfer in Display Control Systems, I. Survey and Variables Included in a Proposed Display Evaluative Index," by Arthur I. Siegel and William Miehle, AD-266 926, Villanova, Pennsylvania, UNCLASSIFIED, September 1961.

The logic and basis of an index for evaluating the information transfer characteristics of the displays in a display-human operator-control system are presented. The purpose of the index is to allow comparative, quantitative evaluation of proposed systems while the systems are in the system concept or the early design stages. The index is related to a logic derived from communications theory and includes five bases. The technique for deriving the scores on which the index depends is described.

84. Applied Psychological Services, "Information Transfer in Display-Controlled Systems, II. Exponent Determination and First Applications of a Display Evaluative Index," by Arthur I. Siegel, William Miehle, Z. Schult, and G. Douglas, AD-272 068, Villanova, Pennsylvania, UNCLASSIFIED, December 1961.

85. Applied Psychological Services, "Information Transfer in Display-Control Systems, III. Further Applications, Reliability, and Validity of a Display Evaluative Index," by Arthur I. Siegel, William Miehle, and Philip Federman, AD-275 198, UNCLASSIFIED, March 1962.

Work continued on a technique for evaluating the information transfer characteristics of the displays

in a display-human operator-control system. The results of applying a quantitative, objective display evaluative technique to two systems are given. Then the inter-user reliability of the technique is presented and held to be adequate.

86. Applied Psychological Services, "Information Transfer in Display-Control Systems, IV. Summary Review of the DEI Technique," by Arthur I. Siegel, William Miehle, and Philip Federman, AD-283 247, Villanova, Pennsylvania, UNCLASSIFIED, June 1962.

87. Applied Psychological Services, "Information Transfer in Display-Control Systems, V. Expansion and Elaboration of the DEI Technique," by Arthur I. Siegel, William Miehle, and Philip Federman, AD-289 368, Villanova, Pennsylvania, UNCLASSIFIED, September 1962.

Strengthening and elaboration of the display evaluative technique, a method for assessing the ability of the displays in a display operator decision control action loop to transfer information and for the operator to act on this information, are described. Additional concepts now included in the DEI are information precursor, information load, transfer criticality, and utilization efficiency.

88. Applied Psychological Services, "Information Transfer in Display Control Systems, VI. A Manual For The Use and Application of the Display Evaluative Index," by Arthur I. Siegel, William Miehle, and Philip Federman, AD-296 374, Villanova, Pennsylvania, UNCLASSIFIED, December 1962.

A manual for applying the Display Evaluative Index (DEI) technique, a technique for measuring the ability of a display-human operator-control system to transfer information and for the operator to act on this information, is presented. The manual contains step-by-step instructions, computational examples, definitions, and sample work forms.

89. Applied Psychological Services, "Quarterly Progress Report, No. 7, 16 December 1962 - 15 March 1963," by Arthur I. Siegel, William Miehle, and Philip Federman, AD-404 732, Wayne, Pennsylvania, UNCLASSIFIED, March 1963.

Several short methods for computing the Display Evaluative Index (DEI) are first described. The first method eliminates the requirements for calculating the values for the three factors comprising the DEI. Although the method does not generally provide an exact value for the DEI, it does provide an approximate value. The method is similar to linear extrapolation and is exact to the extent that the fractional changes of the variables involved are small. A second short computational method is presented which provides exact relative DEI's. This method uses fractional increments and is recommended for use in computing DEI's when: (1) only two or three variations of design are involved, and (2) the increments are known. The third method employs a digital computer for computing DEI's. A validity study indicated that the DEI possesses adequate empirical validity.

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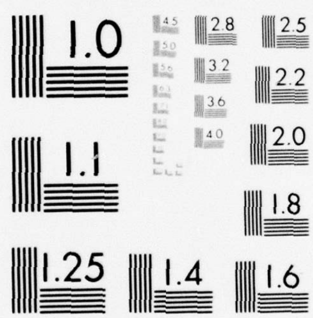

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90. Applied Psychological Services, "Extension of the Display Evaluative Index (DEI) Technique to Multi-Operator Situations," by Arthur I. Siegel and William Miehle, AD-456 019, Wayne, Pennsylvania, UNCLASSIFIED, January 1965.

The Display Evaluative Index (DEI) Technique was extended so as to be applicable to multioperator as well as to unioperator systems. To this end, three additional principles were added to the ten already encompassed within the technique. The multi-operator extension was applied to two separate equipment systems. The obtained results are described and the implications of employing the technique are discussed.

91. Army Personnel Research Establishment By Fleet, "Setting Up Intensity-Modulated Radar Display: A Simple Theory," by L. R. Speight, AD-482 671, (England), UNCLASSIFIED, August 1965.

This paper puts forward a theoretical model of target detection by human observers of intensity-modulated radar displays. Its purpose is to give some generality to the results of an experimental program and to make possible predictions of the way in which various display parameters may affect detection. These predictions can then be subjected to empirical check. The paper starts with an elementary description of the properties of the cathode ray tube. It then divides into two parts: Part I deals with visibility in the absence of noise, and Part II with visibility in its presence.

92. Army Personnel Research Office, "Human Factors Research in Command Information Processing Systems," by S. Ringel, F. L. Vicino, R. Andrews, AD-634 313, Washington, D. C., UNCLASSIFIED, March 1966.

The report describes the scope, rationale, organization, and progress of a command systems research program to provide human factors information needed for performance within complex automated information processing systems. Following a survey of military information processing equipment and operations and future plans for command information processing systems, basic human factors problems were identified and organized around five critical operations--screening incoming data, transforming raw data for input into storage devices, input, assimilation of displayed information, and decision making. A research program was formulated and studies undertaken to yield empirical information about the effects on human performance of (1) characteristics of the information presented (density, amount, etc.); (2) dynamic aspects of information (type, extent, coding of updates); (3) display modes and sensory modalities (group vs. individual displays, multisensory displays); and (4) computer aids to the decision process.
A command systems laboratory was developed to permit simulation of various TOS functions. Findings have suggested the possibility of reduction in storage capacity requirements, number of displays called from storage during a given operational time period, and time required for the total information assimilation-decision process and supported the incorporation and use of information conspicuity coding capabilities in command systems.

93. Battelle Memorial Institute, "Development of Design Criteria for Intelligence Display Formats," by W. D. Hitt, et al., RADC TR-60-201, Columbus, Ohio, UNCLASSIFIED, 21 September 1960.

The objective of this research program was to develop design criteria for intelligence display formats to be used in the SAMOS system. To meet this objective, the following five experiments were conducted: (1) a comparison of vertical and horizontal arrangements of alpha-numeric material, (2) an evaluation of formats for trend displays, (3) an evaluation of methods for presentation of graphic multiple trends, (4) an evaluation of five different abstract coding methods, and (5) an evaluation of the effect of selected combinations of target and background coding on map-reading performance.

A. DATA PROCESSING

94. General Dynamics Electronics, "Conformal Array Sonar System, Real-Time Constraints, Total Computer Capacity, Displays and Ship Interface," Phase I Report, CONFIDENTIAL.

This report has a section discussing the Display and Control Subsystems of a Conformal Array Sonar System in a preliminary design stage. It is an attempt to predict the display and control requirements of the GD/E Integrated Sonar System. A list of the information an ideal display should provide is included. The symbolic mode or computer assisted mode and the analog mode of display presentation are discussed.

The report states that the symbolic mode must be NTDS compatible and that the display cannot depend too heavily on computer time.

95. General Dynamics/Electronics, "Conformal Array Sonar System, Phase I," Final Report, Book 3, UNCLASSIFIED, 30 April 1965.

The section on Signal Classification (Active) is of interest. It discusses the best data formats that should be presented to the operator to enable him to make classification judgments. The classification problem is treated in two parts: the short range case where the target return is relatively undistorted by the medium, and the long range case where varying degrees of noise and multipath are dominant factors. The purpose of long-range classification or pattern recognition is to sort out the likely submarine signal returns for operator display and if possible, associate a number corresponding to the degree of confidence in the classification. In the short-range case, emphasis is placed on the aspect type classification with the signal being made directly available for display. A trade-off between two methods of preselection of raw data is suggested.

96. General Electric Company, "Active Data Processing Requirements for Current Baseline System," Conformal Planar Array Sonar Project, Technical Report C026-48006, Heavy Military Electronics Department, Syracuse, New York, CONFIDENTIAL, 1 April 1966.

This is a final report which describes the processing prepared for the active data handling for the General Electric Baseline C/PAS System. Processing function descriptions and related relative performance for selected alternate configurations have been described. The primary functions of active data handling are considered to be those related to: 1) detection, 2) system control, and 3) other special requirements based on the characteristics of the C/P Array System.

97. General Electric Company, "Data Processing Auxiliary Functions - Data Handling Requirements For Tracking and Data Correction," Conformal/Planar Array Sonar Project, Technical Report C041-48007, Heavy Military Electronics Division, Syracuse, New York, CONFIDENTIAL, 1 April 1966.

The surveillance and tactical modes of tracking are discussed. The surveillance mode is described as one of search and accepting whatever tracking performance can be realized; the tracking mode of operation where the position-keeping of the enemy is of primary importance.

98. General Electric Company, "C/PAS Data Handling/Implementation," Tech Report C043-48008, CONFIDENTIAL, 1 August 1966.

This implementation study had as its objective the synthesis of candidate systems which most effectively perform all of the data handling functions associated with C/PAS. A short review of the objectives and requirements of the active data handling was given. It was pointed out that one of the objectives of the

active data handling is to substantially reduce data rate. Data rate reduction can be accomplished by the techniques of thresholding and channel selection. This report describes the individual processing functions utilizing the approaches of thresholding, channel selection, and energy integration. An analysis of the operational human factors in detection and a functional flow diagram of the active detection process were included.

99. HRB-Singer, Inc., "Display Problems in Aerospace Surveillance Systems," by George Grant and Robert Hostetter, AD-271 440, UNCLASSIFIED, October 1961.

The over-all objective was to determine the information presentation requirements for human data processing roles in future air and aerospace surveillance systems. The conclusions and recommendations listed are based upon information gathered in a comprehensive literature search and pertinent data reflecting the present state-of-the-art in displays and related human data processing roles. From the data available, this report provides: (1) An approach to the problem of specifying and comparing human information presentation requirements; (2) A discussion of display problems and requirements based on currently available research data; (3) A structure for the collection and use of system information requirements in determining display needs; (4) A technique (profile method) for use in screening and evaluating displays in terms of informational requirements; and (5) A program for future research in areas that will optimize man as a component in the system.

100. Human Factors Research, Inc., "Study of Three Methods of Processing Sonar Information For Target Classification," by R. R. Mackie and A. Harabedian, Technical Report 10, Contract NONR 1106(00), CONFIDENTIAL, May 1958.

101. Navy Electronics Laboratory, "Compound Stimulus Encoding of Information for CRT Displays; A Review of the Literature," by C. H. Irwin, Technical Memorandum 317, UNCLASSIFIED, 22 January 1959.

102. Navy Electronics Laboratory, "Auditory Presentation of Information," by R. S. Gales, Technical Memorandum 328, UNCLASSIFIED, 20 March 1959.

103. Navy Electronics Laboratory, "An Improved NTDS Communication and Data Transfer System," Technical Memorandum 330, UNCLASSIFIED, April 1959.

104. Navy Electronics Laboratory, "Proceedings of the Symposium on Undersea Warfare-Data Processing in the NTDS," NEL Report 948, CONFIDENTIAL, December 1959.

105. Navy Electronics Laboratory, "Multidimensional Nonredundant Encoding of a Visual Symbolic Display," by K. M. Newman and A. K. Davis, NEL Report 1048, UNCLASSIFIED, 11 July 1961.

106. Navy Electronics Laboratory, "Data Processing Auxiliary Functions Study," Technical Memo C1248, CONFIDENTIAL, 15 October 1965.

Classification and display parameters are discussed, and an analysis of display-operator interface of the active system is presented.

107. Naval Postgraduate School, "Some Principles of Tactical Data Processing with Emphasis on the Naval Tactical Data System," by J. J. Martin, (1963).

108. Ohio State University, "Information Input and Processing Variables in Man-Machine Systems: A Review of The Literature," by William C. Howell and George E. Briggs, AD-230 997, Research Foundation, Columbus, Ohio, UNCLASSIFIED, September 1960.

109. Remington Rand UNIVAC, "Single Assignment Problem," Report PX 1343-28, Tactical Data System Tech Note 225, 28 April 1960.

110. Remington Rand UNIVAC, "Sector Problems," Report PX 1343-41, Naval Tactical Data System Tech Note 245, January 1961.

111. TRACOR, Inc., "Computation of Sonar Data Display System Target Tracks Using A Digital Computer," by E. A. Tucker, et al., Letter Report, UNCLASSIFIED, 14 March 1961.

112. TRACOR, Inc., "Analysis of Signal Processing and Related Topics Pertaining to the AN/SQS-26 Sonar Equipment," Summary Report II, Document No. 64-290-C, CONFIDENTIAL, 16 October 1964.

B. DISPLAY SYMBOLOGY

113. Air Force Command And Control Development Division, "Effect of Visual Noise on the Judgment of Complex Forms," by John Coules, James S. Duva, George Ganem, AD-249 423, Air Research And Development Command, Bedford, Massachusetts, UNCLASSIFIED, November 1960.

114. Defense Documentation Center, "Experimental Evaluation of Symbolic and Pictorial Displays for Submarine Control," by Robert C. McLane and James D. Wolf, EUR411, UNCLASSIFIED, 30 September 1965.

115. Douglas Aircraft Company, Inc., "An Introduction to the Specification of Optimum Visual Display Design Characteristics," by L. G. Summers, AD-466 961, El Segundo, California, UNCLASSIFIED, June 1961.

116. Dunlap and Associates, Inc., "Optimum Symbols for Radar Displays," by H. M. Bowen and J. Andreassi, AD-227 014, Stamford, Connecticut, UNCLASSIFIED, 1 September 1959.

The purpose of this report was: (1) to find sets of geometric symbols which can be discriminated with high accuracy, especially under degradation, and (2) to find size and stroke width to height ratio for symbols in complex displays.

117. Human Engineering Laboratory, "Radar Symbology: A Literature Review," by Alfreda R. Honigfeld, AD-461 180, Aberdeen Proving Ground, Maryland, September 1964.

This literature review was undertaken to summarize the state-of-the-art of symbology in radar display systems. It reviews the various techniques for coding, extracts general principles for use in designing systems, and recommends areas for further research.

118. IBM Command Control Center, "Effects of Requiring A Track Number to be Associated with a Particular Data Trail," by C. R. Pettie, AD-252 032, Federal Systems Division, Kingston, New York, UNCLASSIFIED, November 1960.

The random walk monitoring program was modified to display an additional 3-digit track number to uniquely identify each vector. Corrective action could be rendered by a subject, only if the vector so identified was that assigned by the program to the trail in question. The effect of the additional discrimination and attendant manual input was compared with the results from the load study.

119. IBM Command Control Center, "Factors Influencing the Legibility of Sage Displays," by Rita M. Halsey, AD-252 034, Federal Systems Division, Kingston, New York, UNCLASSIFIED, November 1960.

Fifteen experiments were conducted with Sage Consoles on the effects of variables such as room illumination (color and amount), tube intensity, intensification time, character size, and display rate. Three procedures were used: one measured reading time for static alpha-numeric material; one measured reading accuracy for changing symbology; and one measured tracking performance. Many interactions were found among the principal variables. The results are applicable to many displays.

120. Mitre Corporation, "Studies in Display Symbol Legibility, Part VIII: Legibility of Common Five-Letter Words," by Gary Kosmider, Marion Young, Glen Kinney, AD-633 055, Bedford, Mass., UNCLASSIFIED, May 1966.

The report describes the findings of a study in symbol legibility which investigated the reading time and errors for common five-letter words when they are projected by a solid stroke and when they are shown by a broken stroke. The latter was produced on a 945-line T Monitor at 10, 7, and 5 active lines per symbol height, with visual size, brightness, contrast, and other viewing condition controlled. The best reading performance resulted from solid-stroke letters. Broken-stroke letters constructed by resolution of 10, 7, and 5 lines resulted in progressively poorer performances.

121. Navy Electronics Laboratory, "NTDS Symbology Study," by J. M. Larkworthy, Technical Memo 325, UNCLASSIFIED, 2 March 1959.

122. Navy Electronics Laboratory, "NTDS Logic Symbology," Report 928, 1 October 1959.

123. Navy Electronics Laboratory, "Readability of Six Symbologies Containing Four Categories of Tactical Data," by C. H. Irwin, Technical Memoranda 363, UNCLASSIFIED, 15 October 1959.

124. Navy Electronics Laboratory, "Naval Tactical Data System (NTDS) Service Test Logic Symbology," by L. R. Collins and J. L. Leonard, Report 1004, UNCLASSIFIED, 13 October 1960.

125. K. M. Newman and A. R. Davis, "Relative Merits of Spatial and Alphabetic Encoding of Information for A Visual Display," <u>J. Eng. Psychol</u>., Vol. 1, No. 3, July 1962.

126. Ohio State University, "Size, Blur, and Contrast As Variables Affecting The Legibility of Alpha-Numeric Symbols on Radar-Type Displays," by William C. Howell, Conrad L. Kraft, AD-232 889, Research Foundation, Columbus, Ohio, UNCLASSIFIED, September 1959.

127. Ramo-Wooldridge, "Display Symbol Recognition," by A. H. Coltin, et al., DSPO Technical Note 6, RADC TN 59-290, AD 314 094, Data Systems Project Office, Los Angeles, California, SECRET, 15 October 1959.

128. Rome Air Development Center, "The Relation of Number of Scan Lines Per Symbol Height to Recognition of Televised Alphanumerics," by Merrill F. Elias, Alvin M. Snadowsky, Edward F. Rizy, Interim Report, AD-608 789, Griffiss Air Force Base, New York, UNCLASSIFIED, October 1964.

129. Vermont University, "A Study of Methods of Coding Visual Information," by Bennet B. Murdock, Jr., Burlington, Vermont, AD-283 658, UNCLASSIFIED, July 1962.

Information presented in a visual display may be coded along one or more dimensions. Studies were made to determine if the transmitted information could be increased by using multi-dimensional stimuli. Near-perfect recognition accuracy was obtained with as many as 400 different stimuli when the three dimensions of color, form, and cross-hatching were used. Recognition accuracy was somewhat better with alpha-numeric stimuli. Alpha-numeric stimuli can be considered a rather complex coding dimension based on shape or form which takes advantage of the individual's extensive past training in language

usage. Both search time and inspection time increased with information load. The results indicate the potential usefulness of alpha-numeric stimuli in the coding of visual information, and suggested the general principle that, for rapid transmission of information, the number of symbols should be minimized while the uncertainty of each individual symbol should be maximized.

IV. OPERATOR PERFORMANCE

A. INFORMATION PROCESSING

130. L. R. Aiken, Jr., and M. Lichtenstein, "Reaction Times To Regularly Recurring Visual Stimuli," Percept. and Motor Skills 18: pp. 713-730 (1964).

131. L. R. Aiken, Jr., and M. Lichtenstein, "Interstimulus and Interresponse Time Variables in Reaction Times To Regularly Recurring Visual Stimuli," Percept. and Motor Skills 19: pp. 339-343 (1964).

132. Bolt, Beranek and Newman, Inc., "Aural and Visual Presentations of Radar Information," Final Report, BBN Report 594, by JCR Licklider, Cambridge, Massachusetts, SECRET, 1 October 1958.

133. BuPers, "NTDS Operator Performance Decrement at Various Track Load Levels," Personnel Research Division, CONFIDENTIAL, March 1962.

This study determined what types of performance decrements can be anticipated under various track load levels of NTDS CIC operation and identified possible means of preventing or correcting these decrements.

134. FCPCP, "Naval Tactical Data System Split Track Identification Study," by A. A. Holsten and G. O. White, Formal Report 3048, CONFIDENTIAL, 18 August 1964.

Problems pertaining to track splits, merging tracks, and problems associated with late detections are treated. Operator verification of a few automatic best-guess decisions made by the equipment.

135. Human Factors Research, Inc., "Recent Literature Bearing On Psychological Problems Associated With Sonar Operator Performance," by H. D. Kimmel, R. R. Mackie and C. L. Wilson, Technical Report #4, Contract NONR 1106(00), UNCLASSIFIED, July 1956.

136. Human Factors Research, Inc., "Six Years of Research on Human Factors Problems in ASW, A Summary," by Robert R. Mackie, Technical Report 206-28.

137. Human Factors Research, Inc., "A Report of Two Experimental Studies Designed To Train Sonar Men in Target Classification," by H. D. Kimmel, R. R. Mackie and R. A. Gavin, Technical Report 6, Contract NONR 1106(00), CONFIDENTIAL, June 1957.

138. Human Factors Research, Inc., "A Study of the Utility of Time Compressed Audio and Video Sonar Information For Target Classification," by H. D. Kimmel, R. A. Gavin, and R. R. Mackie, Technical Report 7, Contract NONR 1106(00), CONFIDENTIAL, June 1957.

139. Human Factors Research, Inc., "Doppler Judgments of Sea-Recorded Sonar Returns At Several Pulse Lengths," by H. D. Kimmel, E. L. Parker and R. R. Mackie, Technical Report 11, Contract NONR 1106(00), CONFIDENTIAL, Feb. 1958.

140. Human Factors Research, Inc., "The Applicability of Classification Principles Developed From SQS-10 and 11 Sonar Displays to SQS-4 Sonar Displays," by R. A. Gavin and R. R. Mackie, Technical Report 13, CONFIDENTIAL, July 1958.

141. Human Factors Research, Inc., "A Study of Target Detection by Sonar Operators," by C. H. Baker and A. Harabedian, EUR 181, June 1962.

142. Human Factors Research, Inc., "Doppler Detection and Display System," Contract NObsr 93226, PR1, CONFIDENTIAL, May 1965.

143. Navy Electronics Laboratory, "Operator Doppler Discrimination Error as a Function of Increased Sonar Range," by J. H. Stroessler, Technical Memorandum 154, UNCLASSIFIED, 6 December 1955.

144. Navy Electronics Laboratory, "The Improvement of Doppler Discrimination Ability," by J. H. Stroessler, Technical Memorandum 198, UNCLASSIFIED, 27 July 1956.

145. Navy Electronics Laboratory, "Sonar Target Detection as a Function of PPI Size," by H. F. Sahlein, Technical Memorandum 221, CONFIDENTIAL, 14 November 1956.

146. Navy Electronics Laboratory, "Track Detection on a Simulated LORAD Display," by J. F. Strickland, H. R. Eady and P. M. Hamilton, Technical Memorandum 386, UNCLASSIFIED, 3 February 1960.

147. J. O'Hanlen, Jr., A. Schmidt, and C. H. Baker, "Sonar Doppler Discrimination and The Effect of a Visual Alertness Indicator Upon Detection of Auditory Sonar Signals in a Sonar Watch," Human Factors, Vol. 7, pp. 129-139, April 1965.

Previous research reported that the ability to make auditory pitch discriminations is impaired in some subjects by prolonged listening to sonar returns. As a special type of pitch discrimination, discrimination of doppler is of importance in classifying sonar signals. An experiment was performed to determine whether or not listening to sonar returns for 90 minutes impairs the ability to discriminate doppler. No impairment was found. A second aim of this experiment was to evaluate the effectiveness of an alertness indicator when listening for sonar signals. With the indicator 16 per cent more signals were detected than without it.

148. Sylvania Electronic Systems, "Integration of Concurrent Visual and Auditory Messages," Final Technical Report, AD-621 278, UNCLASSIFIED, July 1965.

Two experiments were performed involving the concurrent presentation to human subjects of two messages, one aduitory and one visual, followed by a question requiring information from both messages. The results indicated that bimodally-presented information can be integrated for decision making. However, there was no evidence of an advantage to bimodal presentation as a means of unburdening an overloaded sense. The implications of the results for displays and communications in complex control centers are discussed and directions for future research are suggested.

149. System Development Corporation, "Information Displays and Information Processing Tasks," by Harriet W. Foster, EUR-109, September 1964.

150. TRACOR, Inc., "Summary Report of Results, Conclusions and Recommendations from a Psychophysical Study of The Relative Detectability of Target Tracks in Simulated Passive Sonar Displays," by Bruce H. Deatherage, 63-231-U, Austin, Texas, UNCLASSIFIED, 6 September 1963.

151. TRACOR, Inc., "The Effects of Signal Probability and Observation Period Duration Upon Signal Detection Performance," by Anne Blocker Blosser, 65-277-U, Austin, Texas, UNCLASSIFIED, August 1965.

152. Tufts University, "Literature Survey on Human Factors in Visual Displays," by Philip B. Sampson and A. Edward Wade, AD-262 533, Medford, Massachusetts, UNCLASSIFIED, June 1961.

153. University of Southern California, "The Role of Humans in Complex Computer Systems; Tactical Data Processing," Psychology Department, Electronics Personnel Research Contract NONR-228(02), TR 27, CONFIDENTIAL, February 1959.

This report is the final of four reports. The present report interprets the information in the three preceding reports in terms of the NTDS specifically, and military tactical data-processing systems in general. It discusses characteristics of these systems which have implications for the personnel side of their development. Conclusions and recommendations are suggested for application in the continued development of NTDS.

154. J. C. Webster and R. B. Chaney, Jr., "Information and Complex Signal Perception," Proc. Symposium on Models For The Perception of Speech and Visual Form, November 1964.

155. C. T. White and A. Ford, "Eye Movements During Simulated Radar Search," J. Opt. Soc. Am. 50: pp. 909-913, (1960).

156. Wright Air Development Center, "A Comparison of the Visual and Auditory Senses As Channels For Data Presentation," by R. H. Henneman and E. R. Long, WADC TR 54-363, AD-61 558, UNCLASSIFIED, August 1954.

It is contended in this report that the choice between the eyes and the ears as sense channels for the presentation of information to the human operator rests upon the specific demands of various operational situations. Three sets of variables impose demands for the presentation of data, some of which have implications for visual or auditory presentation. These three sets of demands are: (1) demands imposed by response variables (e.g., orientation in space, fine quantitative comparison, rapid referability); (2) demands imposed by operator variables (e.g., previous habits, fatigue, motivation); and (3) demands imposed by special environmental conditions favoring one or the other sense channel (e.g., ambient noise, sudden changes of illumination, excessive vibration).
The stimulus properties of light and sound differ; the receptor characteristics of vision and audition also differ. It is possible, by matching these distinguishing sense characteristics with specific demands of

particular situations, to suggest some "division of labor" between the two sense channels for purposes of data presentation. Four principal categories of demands for informational input have been proposed as follows: (1) typical demands for visual presentation; (2) typical demands for auditory presentation; (3) typical demands served by either sense alone; (4) typical demands for dual audio-visual presentation.

B. VIGILANCE

157. Human Factors Research, Inc., "Human Factors Problems in ASW. Review and Critique of the Literature On Vigilance Performance," by J. L. McGrath, et al., Technical Report 1, Los Angeles, California, UNCLASSIFIED, December 1959.

This report is a review of work on vigilance performance. Problems requiring additional research in this area are identified, and an annotated bibliography of the literature on vigilance performance is included.

158. Human Factors Research, Inc., "Human Factors Problems in ASW. A Study of Individual Differences in Vigilance Performance," Technical Report 2, Los Angeles, Calif., UNCLASSIFIED, January 1960.

An experiment to determine the reliability and validity of individual differences in both auditory and visual vigilance is reported. Changes in performance over time and differences in auditory and visual performance were investigated.

159. Human Factors Research, Inc., "Human Factors Problems in ASW. The Probability of Signal Detection in a Vigilance Task As A Function of Inter-Signal Interval," Technical Report 3, Los Angeles, California, February 1960.

This is a report of an experiment on the effect of three different inter-signal intervals on audio and visual detection tasks performed under two different signal rates. The inter-signal intervals used were: time since previous signal, time since last signal detected, and time since the last signal missed. The signal rates used were 6 or 30 signals per hour.

160. Human Factors Research, Inc., "Human Factors Problems in ASW. An Exploratory Study of Correlates of Vigilance Performance," Technical Report 4, Los Angeles, California, UNCLASSIFIED, February 1960.

The research described in this report was intended to serve as a starting point in the development of predictors of vigilance performance. Its purpose was to investigate the relationships between a large number of behavioral measures and criteria of performance on vigilance tasks. The effort was directed toward ascertaining the types of behavioral measures, rather than the specific measurement instruments, that would be promising predictors of vigilance performance. The results of this investigation are to be used to guide further research in the development of specific selection instruments.

161. Wright Air Development Center, "Experiments on Vigilance: Duration of Vigil and the Decrement Function," by H. J. Jerison, WADC TR 58-369, UNCLASSIFIED, December 1958.

Results of previous experiments on vigilance were reanalyzed for data on human performance during short (half-hour) and long (two-hour) vigils. The analysis indicated that length of vigil did not affect either the initial or terminal level of performance.

V. MAINTENANCE

162. General Electric Company, "Programmed Maintenance Plan for the AN/SQS-26 Test and Evaluation Program," 30 September 1964.

163. Navy Electronics Laboratory, "Calculating the Maintainability of Electronic Equipments or Systems," by E. S. Beam, Technical Memorandum 242, UNCLASSIFIED, 25 April 1957.

164. Navy Electronics Laboratory, "Human Factors in the Design and Utilization of Electronics Maintenance Information," by J. H. Stroessler, J. M. Clarke, P. A. Martin, and F. T. Grimm, Report 782, UNCLASSIFIED, 31 May 1957.

165. Navy Electronics Laboratory, "Human Factors in NTDS Maintenance," by C. E. Cunningham, Technical Memorandum 305, UNCLASSIFIED, September 1958.

This paper reviews the state-of-the-art of subminiaturized construction, the maintenance displays available, the Navy's maintenance capability, and the general maintenance philosophy that are applied to existing subminiaturized systems.

166. Navy Electronics Laboratory, "Glossary of Maintenance Terms As Used in the Naval Tactical Data System," by S. Webb and M. L. Sturgeon, Technical Memorandum 385, UNCLASSIFIED, 3 February 1960.

167. Navy Electronics Laboratory, "Current Trends in Naval Electronic Maintenance," by F. W. Smith and K. R. Murch, Report 972, UNCLASSIFIED, 20 September 1960.

168. Navy Electronics Laboratory, "NTDS Display Maintenance Tests for Use with NTDS Unit Computer AN/USQ-17," Technical Memorandum 539, May 1962.

169. TRACOR, Inc., "Reliability, Maintainability, and Availability Requirements for AN/SQS-26CX Sonar Equipment," Memo 688E-040, by G. T. Kemp and J. M. Young, 63-267-C, Also Addendum 1, CONFIDENTIAL, March 2, 1964; Addendum: April 13, 1964.

170. TRACOR, Inc., "Reliability/Maintainability Guidelines for Sonar Specification Writers," by C. J. Benning and H. C. Gray, Document No. 65-192-U, Technical Memorandum, UNCLASSIFIED, June 18, 1965.

VI. PERSONNEL AND TRAINING

171. Aerospace Medical Research Labs., "A Bibliography of Reports Issued by the Behavioral Sciences Laboratory: Engineering Psychology, Training Psychology, Environmental Stress, Simulation Techniques, and Physical Anthropology - 1946 - 1962," by L. Jean Thomas, AD-402 386, Wright-Patterson Air Force Base, Ohio, UNCLASSIFIED, March 1963.

172. BuPers, Personnel Research Division, "Training Feedback Study of NTDS Maintenance Personnel," December 1962.

173. BuPers, "System Analysis of NTDS Operator and Maintenance Billets and Duties," Personnel Research Division Report ND 63-52, April 1963.

174. General Electric Company, "Instructor Guide For the AN/SQS-26 XN-2 Major Modification Training Program."

175. Human Factors Research, Inc., "Sonar Classification Skill: The Present State of Knowledge," by R. R. Mackie, R. A. Gavin, and C. L. Wilson, Contract NONR 1106(00), Technical Report 5, CONFIDENTIAL, July 1956.

176. Human Factors Research, Inc., "Learning Problems in Sonarmen Training; Final Report: Summary of Research Performed 1954-1956," by R. R. Mackie, Contract NONR 1106(00), CONFIDENTIAL, September 1958.

177. Human Sciences Research, Inc., "Personnel and Training Requirements of the AN/SQR-13 (PADLOC I BASIC) Sonar System," by C. R. Covonius and J. E. Wise, McLean, Virginia, HSR-RR-64/9-KE, CONFIDENTIAL, August 1964.

This report presents personnel manning and training requirements for the AN/SQR-13 (PADLOC I BASIC) Sonar System. Included in this report are a functional analysis of the PADLOC I System, an Operational Sequence Diagram, a description of operator procedures, and the skills and knowledges demanded of an operator, predicted maintenance requirements, billet descriptions, recommended operating and maintenance personnel assignments, the training programs required to obtain proficient personnel, and a suggested approach to future personnel manning and training research.

178. Navy Electronics Laboratory, "Synthetic Environments for NTDS CIC Training," Technical Memorandum 487, 1 September 1961.

179. Naval Personnel Research Activity, "Preliminary Personnel Requirements for Future Sonar Equipments: AN/BQQ-1 and AN/SQS-26," No. 139, San Diego, California, CONFIDENTIAL, February 1959.

180. Naval Personnel Research Activity, "Personnel Implications of Oceanography as Related to the AN/SQS-26 Sonar," ND 64-23 (N), Washington, D. C., CONFIDENTIAL, November 1963.

181. Naval Personnel Research Activity, "Preliminary Research Memorandum Personnel and Training Requirements for the AN/SQS-26 BX Sonar Set," ND 64-58, Washington, D. C., CONFIDENTIAL, May 1964.

182. Naval Personnel Research Activity, "Predicted Personnel Requirements for SEA HAWK Integrated Combat System," PRASD Memorandum Report 64-11, San Diego, California, CONFIDENTIAL, June 1964.

183. Naval Personnel Research Activity, "Initial Personnel Requirements for SEA HAWK Integrated Combat System (Phase II Report)," PRASD Memorandum Report ND 64-26, San Diego, California, CONFIDENTIAL, December 1964.

184. Naval Personnel Research Activity, "Initial Comparative Personnel Requirements Summary (DE-1040/DE-1048)," San Diego, California, CONFIDENTIAL, May 1965.

185. Naval Personnel Research Activity, "ASW Ship Command and Control Project Personnel Research Progress Report," San Diego, California, June 1965.

186. Naval Personnel Research Activity, "Initial Personnel Requirement for DE-1048 ASW Ship Command and Control Project," by E. A. Koehler and H. C. McDowell, San Diego, California, CONFIDENTIAL, June 1965.

187. Naval Personnel Research Activity, "Training Compatibility Study of the Naval Tactical Data System(NTDS), the Airborne Tactical Data System (ATDS), and the Marine Tactical Data System (MTDS)," by H. G. Smith and H. R. Rignely, Res. Memo SRM 65-9, June 1965.

188. Naval Personnel Research Activity, "Survey of Shipboard NTDS Training," by H. Smith and H. Chambers, Res. Memo SRM 66-5, August 1965.

189. Naval Personnel Research Activity,"The AN/SQS-26 and Conformal/Planar Array Sonar Systems, Part I, Systems Characteristics and Rationals Behind the Manning Requirements," by Eldridge A. Errickson, Res. Memo SRM-66-29, San Diego, California, CONFIDENTIAL, May 1966.

190. Naval Personnel Research Activity, "The AN/SQS-26 and Conformal/Planar Array Sonar Systems, Part II - Personnel and Training Requirements," by Eldridge A. Errickson, Res. Memo SRM-66-29, San Diego, California, CONFIDENTIAL, May 1966.

191. Naval Personnel Research Laboratory, "AN/SQS-26 (AN) Maintenance Training Feedback Study," by R. E. Holland, N. R. Skoog, and J. A. Nobile, Bureau of Naval Personnel WRM No. 65-57, CONFIDENTIAL, June 1965.

192. Naval Personnel Research Laboratory, "Sonar Technician Rating Structure," by Henry C. Rosicky, WRM No. 66-2, July 1965.

193. Naval Personnel Research Laboratory, "AN/SQS-26CX and AN/SQS-26AX Retrofit Personnel and Training Requirements," by N. R. Skoog and J. A. Nobile, CONFIDENTIAL, October 1965.

194. Naval Training Device Center, "Human Factor Analysis of Team Training," by J. E. Horrocks and R. Goyer, Technical Report 198-1, CONFIDENTIAL, 26 October 1959.

195. Personnel and Training Branch, Psychological Sciences Division, Department of the Navy, "Human Factor Problems in Anti-Submarine Warfare, Sonar Equipment Design and Maintenance Training in Selected European Navies," Technical Report 206-34, by R. R. Mackie and E. L. Parker, Contract NONR 2649(00) NR 153-199, Santa Barbara, California, CONFIDENTIAL, October 1965.

196. Personnel Research Division, "Personnel and Training Requirements, AN/SQS-26 Sonar System (XN-2), Preliminary Research Memo, CONFIDENTIAL, March 1962.

197. Psychological Research Association, "Personnel Requirements Information for the NTDS Maintenance System," Report 60-16, 1 May 1960.

198. Psychological Research Association, "Maintenance Personnel Requirements Information for NTDS," Report 60-38, 30 July 1960.

199. Psychological Research Assoc., "Maintenance Personnel Training Recommended for the NTDS," Interim Report, Contract NONR 2980(00), 1 December 1960.

VII. GENERAL REFERENCES

200. Aerospace Medical Research Labs., "A Bibliography of Aerospace Medical Division Reports in the Fields of Engineering Psychology and Training Psychology, 1945-1960," by Sandra A. Stevenson, AD-243-253, Wright-Patterson Air Force Base, Ohio, UNCLASSIFIED, May 1960.

201. American Institute For Research, "A Checklist for Human Factors in Operational Suitability Tests," by Robert FitzPatrick, AFSWC-TR-55-17, 31 August 1955.

A checklist to be considered in planning for human factors in Operational Suitability Tests (OST's) is presented. OST's require attention to human factors, in order to evaluate whether new equipment will function adequately in operations. The following topics are discussed and suggestions made: planning an OST; collecting human factors data during an OST; job analyses; observation of personnel errors during an OST; and interpreting ten results of an OST.

202. ASTIA, "Human Engineering, A Report Bibliography, AD-274 800, UNCLASSIFIED, May 1962.

203. Cornell University, "Decision Making--An Annotated Bibliography," by P. Wasserman and F. S. Selander, Ithaca, New York, UNCLASSIFIED, 1958.

This document is designed to provide a selected and annotated list of books, articles and documents which will serve as a general and broadly conceived introduction to decision making. The references are divided into eight categories: the decision-making process;

values and ethical considerations in decision making; leadership as a factor in decision making; psychological factors in decision making; decision making in small groups; community decision making; communications and information handling; and mathematics and statistics in decision making.

204. Electronics Systems Division, "Bibliography of Human Factors Research with Abstracts, 1954 thru 1962," by J. P. Gonon, Hanscom Field, Bedford, Massachusetts, Report TDR-63-603, UNCLASSIFIED, August 1963.

205. Lawrence J. Fogel, Biotechnology: Concepts and Applications, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1963.

206. Robert M. Gagné and Others, Forword by Arthur W. Melton, Psychological Principles in System Development, Holt, Rinehart and Winston, New York, June 1965.

207. Human Resources Research Office, "Bibliography of Human Factors in Radar Operation and Maintenance."

208. Human Resources Research Office, "Bibliography of Publications as of 30 June 1963."

209. Library of Congress, "Human Engineering; A Selected Bibliography and a Guide to the Literature," ARC Report 426C, CONFIDENTIAL.

210. Library of Congress, "Human Engineering; A Selected Bibliography and a Guide to the Literature," ARC Report 426U, UNCLASSIFIED.

211. Davis Meister and Gerald F. Rabideau, Human Factors Evaluation in System Development, John Wiley & Sons, Inc., 1965.

212. Clifford T. Morgan, Alphonse Chapanis, Jesse S. Cook, III, and Max W. Lund, Human Engineering Guide to Equipment Design, McGraw-Hill Book Company, Inc., 1963.

213. National Research Council, "Human Factors in Undersea Warfare," Washington, D. C., 1949.

214. Naval Electronics Laboratory, "Bibliography of Human Factors Reports," January 1965.

215. Naval Research Laboratory, "Engineering 4-Branch Bibliography," by C. E. Burke, Bibliography 27, October 1965.

216. Naval Training Device Center, "Bibliography of Unclassified Engineering Reports," NavExos P-1491, 15 July 1961.

217. Office of Naval Research, "Human Engineering Bibliography 1961-1962," ACR-86, October 1963.

218. Henry H. Poole, Fundamentals of Display Systems, Spartan Books, 1966.

This book provides fundamental data and illustrates basic techniques used in the design and development of display systems. It describes most types of displays in current use and discusses systems still in the research stage. The book is broken down into five major sections: cathode ray tube techniques; other display techniques; display systems; future display techniques; and, related areas. A section on human engineering considerations is included.

219. San Diego State College Foundation, "A Human Engineering Bibliography," by I. N. McCollom and A. Chapanis, Technical Report 15, San Diego, California, UNCLASSIFIED, November 1956.

The Bibliography contains 5,655 references in Human Engineering, broken down into the following areas: general references, methods, facilities, and equipment; man-machine systems; visual problems; auditory problems; speech communication; other sensory input channels; comparison and interaction among sensory input channels; the design of controls and integration of controls with displays; control systems; design and layout of workplaces, equipment and furniture; body measurements and movements; higher mental processes; simulators and proficiency measuring devices; environmental effects on human performance; behavioral efficiency, fatigue, and human capacities; and operator characteristics for specific jobs.

220. S. S. Stevens, (Ed.), Handbook of Experimental Psychology, Wiley, New York, 1951.

221. John A. Swets, Signal Detection and Recognition by Human Observers, John Wiley & Sons, Inc., 1964.

222. TRACOR, Inc., "A New Active Sonar Visual Display Console Design," by B. H. Deatherage, et al., Special Report, CONFIDENTIAL, 30 October 1961.

223. Tufts College, "Handbook of Human Engineering Data," AD-43 650 and AD-85 211, Medford, Massachusetts, 1952.

224. Tufts University, "Human Engineering Bibliography, 1957-1958," by E. V. Saul, et al., ONR Report ACR-43, Medford, Massachusetts, UNCLASSIFIED, October 1959.

The general objective of the contract under which the present report was prepared is to conduct long term research required to develop an Information Analysis Service in the area of human engineering designed to meet the needs of individuals responsible for the development of equipment operated by military personnel. One method for partially meeting this objective is to prepare and disseminate useful bibliographies. The present bibliography is one of a series which it is hoped meets the criterion of utility.

225. W. E. Woodson, Human Engineering Guide for Equipment Designers, University of California Press, Berkeley, California, UNCLASSIFIED, 1954.

This is a guide to aid the designer in making optimum decisions wherever human factors are involved in man-operated equipment, by providing a central source for information about the human operator, by pointing up the relative importance of certain variables, and by indicating solutions for typical design problems. The guide contains chapters on: Design of Equipment and Workspace, Vision, Audition, Body Measurement; other factors are: design and use of visual displays, design and arrangement of operating equipment and auditory problems.

226. Wright Air Development Center, "Visual Presentation of Information," by C. A. Baker and W. F. Guther, TR-54-160, UNCLASSIFIED, August 1954.

This report provides a compilation of general human engineering recommendations and presents some of the supporting data which should aid the engineer in providing the most satisfactory visual presentations of information. The report is divided into seven chapters entitled: Mechanical Indicators, Warning Devices, Cathode Ray Tubes and Signal Coding, Printed Materials, Instrument Panel Layout, Lighting, and Visual Detection and Identification. A selected bibliography is also included as an aid to the user.

227. Wright Air Development Center, "Procedures for Including Human Engineering Factors in the Development of Weapon Systems," by H. P. VanCott and J. W. Altman, TR-56-488, Wright-Patterson Air Force Base, Ohio, UNCLASSIFIED, October 1956.

This report describes the process of integrating human factors considerations into the design of a system. It includes procedures for identification and analysis of functions, description of operator performance, workspace layout and equipment design, and system evaluation, as well as data and references on human capabilities and limitations.

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APPENDIX B

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